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Cockpit Simulation Study of Use of Flight Path Angles for Instrument Approaches

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF TABLES

LIST OF TABLES (CONT'D)

SUMMARY

This report presents the results of a piloted-simulation experiment aimed at evaluating the addition of flight path angle (FPA) symbology to a base-line transport airplane electronic attitude director indicator (EADI) for control and monitoring during flight director instrument approaches. Three electronic display formats were evaluated. Each format was comprised of a base-line set of display parameters consisting of: pitch and roll attitude; indicated airspeed; radar altitude; fast/slow, glide slope and localizer deviation; and pitch and roll, flight director commands. The two format variations about the basic display included the addition of, and specific symbology for, flight path angle, drift angle and flight path acceleration information. The evaluation was conducted during 3° straight-in approaches with two different wind profiles characterized by lateral, longitudinal and vertical shears and turbulence conditions. Flight path tracking data and pilot subjective comments were examined with regard to the pilot's ability to capture and maintain the localizer and glide slope when using each of the three display formats.

The results of this experiment show that the addition of FPA information to a basic EADI format did not significantly improve lateral or vertical tracking performance during the approach to landing under the simulated wind profiles. Pilot workload required to assess the presence of lateral and vertical wind shears was reduced, however, by the display of flight path and drift information.

INTRODUCTION

The present trend within the airline/airframe community is to utilize color electronic displays for primary cockpit instrumentation. The capability provided by this equipment, to present integrated information in new display formats, requires serious consideration due to the potential benefits attainable in terms of decreased pilot workload and increased flight path performance. Limiting factors imposed on these new display formats relate to the computational capacity of the airborne computers and, more practically, the costs associated with pilot training. That is, the new display formats cannot be so complicated as to exceed the capability of the prospective digital computer performing the display computation and generation, and the display must be easily interpretable by the pilot with a minimum of retraining time. For the EADI for the 757/767 aircraft, Boeing is attempting to minimize the transition problem from the electromechanical instruments to the cathode ray tube (CRT) displays by defining a display format that is very similar to the electromechanical ADI's presently flying in the DC-10, L-1011, and B-747.

Research and development activities performed by NASA as part of the Terminal Configured Vehicle (TCV) Program have shown the benefits of utilizing flight path angle information and perspective runway symbology on a vertical situation display in conjunction with a velocity vector control wheel steering mode. By using the flight path information and the perspective runway, as depicted in Figure 1, the pilots were able to fly ILS approaches without flight director commands. These activities were performed via simulation and flight test experiments and are reported on in reference 1 and 2, respectively.

The study described herein provides a logical extension of these experiments by NASA; however, it utilizes a more typical present-day airline display with flight director information as a base-line. For this display, an EADI format similar to that defined by Boeing for the 757/767 Electronic Flight Instrument System (EFIS) procurement was chosen. This display format, without flight path information, was used to establish a reference from which comparisons could be made with two variations of this base-line. The first variation, specified by Boeing as an EFIS EADI option, includes the flight path information tested by NASA in their experiments. The second variation, created by Bendix for this study, provides a simple addition of flight path angle to the base-line display.

This report presents the results of a piloted-simulation experiment aimed at evaluating the addition of flight path information, via these three EADI display formats, during flight director ILS approaches. Performance and workload data is presented for each of the wind conditions studied, and pilot comments are related to the analytical results obtained. The experiment was conducted in the Bendix Flight Systems Division fixed-base transport cockpit simulator during November 1980. Four airline pilots participated in the experiment as test subjects.

SIMULATOR

The Bendix transport simulator is a fixed-base cockpit simulator comprised of a DC-8 cab with modern instrumentation, a Data General ECLIPSE S/230 Minicomputer System and a Bendix computer system for input/output handling. The complex is shown in Figure 2 and the pilot's instrument panel is shown in Figure 3.

The simulation model is based on the DC-10 Series 30 aircraft. This includes the DC-10's" equations of motion; pitch and roll flight director control laws; yaw damper control law; control wheel steering algorithms; and, actuation and autothrottle systems. The ILS and airport geometry shown in Figure 4, is based on Runway 13-31 at the FAA Technical Center in Atlantic City, New Jersey. All computations, except the CRT display generation, were performed within the ECLIPSE every 50 milliseconds. The EADI display formats were generated within the Bendix display computer every 100 milliseconds.

SYMBOLS AND ABBREVIATIONS

ADI	attitude director indicator
ALT HLD	altitude hold mode annunciation
B6	FAA wind profile B6
B7	FAA wind profile B7
cm	centimeter
CRT	cathode ray tube
df	degrees of freedom
D_1	display format number 1
D_2	display format number 2
D_3	display format number 3
EADI	electronic attitude director indicator
EFIS	electronic flight instrument system
FAA	Federal Aviation Administration
F_C	calculated test statistic
FPA	flight path angle
F_T	value for confidence level with (m, np) degrees of freedom
ft	feet
GS	glide slope
GS CAP	glide slope capture mode annunciation
GS TRK	glide slope track mode annunciation
HSI	horizontal situation indicator
IAS	indicated airspeed

SYMBOLS AND ABBREVIATIONS (CONTINUED)

IAS HLD	indicated airspeed hold mode annunciation
ILS	instrument landing system
in	inches
LOC TRK	localizer track mode annunciation
m	meters
MAC	mean aerodynamic chord
MS	mean square value
NASA/SRI	National Aeronautics and Space Administration/Stanford Research Institute
RMS	root mean square
S	standard deviation
s	Laplace operator
SS	sum of squares
TCV	Terminal Configured Vehicle
W_1	evaluation window number 1
W_2	evaluation window number 2
W_3	evaluation window number 3
$\bar{x}$	statistical RMS mean value

EXPERIMENT DESIGN

The experiment was designed to evaluate pilot performance using three variations of a typical EADI display with and without flight path symbology. A high workload environment was simulated by requiring flight director approaches to 100 feet of altitude under severe wind shear and turbulence conditions. Each of three display formats were flown with two different winds, and four repeats were made for each display/wind combination per pilot.

The evaluation process was both qualitative and quantitative. Subject pilot opinion and questionnaire evaluation were sought with respect to the pilot's: (1) ability to understand and use the displayed information; (2) acceptance and confidence in the display formats, (3) use of the flight path symbology to detect the presence and direction of wind shears; and, (4) mental and physical workload. Aircraft tracking parameters were recorded and analyzed, and pilot wheel and comumn inputs were examined to measure physical activity.

DISPLAYS

The three display formats used in this study were programmed on a Bendix 3-color beam penetration CRT with a viewable area of 14.48 x 14.48 cm (5.7 x 5.7 in.). As shown in Figure 3, this unit is mounted directly in front of the control wheel on the left side of the simulator's instrument panel. Although the CRT is somewhat larger than the A rinc size A package utilized on the 757/767, this is not of critical importance to the results of the study. A second difference, which may be more significant, relates to the color capability of the simulator display unit versus the 757/767 unit. The unit used in the study provides the colors red, green, and amber, while the Boeing unit provides 7-colors, including red, green, blue, and mixtures of these. The Boeing unit can, therefore, use color in a more effective manner to separate display parameters and declutter the screen. Although this may have had some bearing on the outcome of the sutdy, it is extremely doubtful that it would be crucial based on the analytical results and pilot commentary obtained.

Display format 1, shown in Figure 5, is the baseline EADI presentation. It provides pitch and roll attitude information via a standard horizon line and sky/ground texture which move behind a fixed aircraft symbol. The pitch scale is graduated in 5 degree increments. A roll pointer moves along a scale at the top of the screen with indications of 10, 20, 30, 45, and 60 degrees.

The display provides speed information using a fast/slow deviation scale which is referenced to a pilot-selected speed setting. The speed setting for the flight condition utilized in the study was 150 knots. The display also provides a window above this scale with a digital readout of indicated airspeed. ILS deviation information is included via the glide slope and expanded localizer scales. The glide slope indicator provides a full scale deviation (2 dots) of $\pm$.7 degrees about the runway's glide path angle. The expanded scale localizer indicates lateral deviation about the localizer beam. Unlike theinformation on the horizontal situation indicator (HSI), which provides a full scale (2 dots) reading of $\pm$2 degrees, the ADI expanded localizer scale provides greater resolution about beam center but is useable only within 1/2 dot or 0.5 degrees. Above the glide slope deviation scale, a window is provided with a digital readout of radar altitude. Above this, a decision height indication illuminates when the aircraft descends below the pilot-selected altitude. Autopilot/flight director and autothrottle mode annunciation is provided in the lower left and right corners of the screen. For this study: the autothrottle always remained in the IAS hold (IAS HLD) mode; the roll flight director always remained in localizer track (LOC TRK); and, the pitch flight director transitioned from altitude hold (ALT HLD) to glide slope capture (GS CAP) to glide slope track (GS TRK) based on the DC-10 transition logic. The command information on the display is provided by the cross pointers which move laterally and vertically with respect to the square at the center of the aircraft symbol. These command bars are driven by the DC-10 altitude hold and ILS control laws.

Display format 2, shown in Figure 6, adds the flight path symbology to the baseline EADI described above. The wedge-shaped symbols move perpendicular to the horizon line to indicate flight path angle with respect to the pitch altitude scale. They also move laterally, while remaining parallel to the horizon line, to provide a gross indication of drift angle. The rectangular symbols, shown outside the wedges, depict the aircraft's flight path acceleration. The zero reference for the acceleration term is the flight path angle wedge. This parameter provides significant lead information for flight path activity. The equations used to generate the flight terms just described are shown below:

(1) $\text{Flight Path Angle} = 57.3 \ \dfrac{\text{Vertical Speed}}{\text{Ground Speed}}$

(2) Drift Angle = Ground Track - Heading

(3) $\begin{array}{l}\text{Flight Path}\\ \text{Acceleration}\end{array} = \dfrac{1}{s+1} \ (\text{Ground Speed Rate})$

Display format 3, shown in Figure 7, differs from the baseline EADI due to the addition of the flight path angle "V" symbology. This consists of

a flight path angle reference box which is centered between the wheels of the aircraft symbol and a "V" which opens and closes, both up and down, to indicate the aircraft's flight path angle with respect to the reference. The "V" always opens or closes in a direction perpendicular to the aircraft symbol. It is not tied to the horizon or the pitch scale. The reference box has been located with respect to the aircraft symbol and remains fixed on the screen in a position which corresponds to a standard ILS glide path. The top of the box corresponds to 2.5 degrees, the middle 2.75 degrees and the bottom 3 degrees. Thus, if the pilot keeps the tip of the "V" inside the reference, he is maintaining a flight path between 2.5 and 3 degrees down.

EXPERIMENTAL TASK

The experimental task required the pilot to capture and track a 3° glide slope while maintaining the localizer from 364.8m (1200 ft) to 30.48m (100 ft.) of altitude using the displayed flight director pitch and roll commands as the primary control information. Flight path angle information was used, at the pilot's discretion, to support the flight director command information to maintain the task profile shown in Figure 8. All pilots were instructed tomonitor their progress and performance along the profile utilizing normal cross-check parameters.

TEST SUBJECTS

Four commercial airline pilots were used to evaluate the displays. Two of the pilots were rated for the DC-10, and the other two pilots were rated for the B-727. Three of the four subject pilots had some previous experience with the cross pointer type flight director display. The other pilot had only used single cue flight director presentations. None of the pilots had any experience in the test simulator or had participated in the design of the display formats.

TEST PROCEDURE

Each subject pilot was thoroughly briefed prior to performing the experiment. A detailed description of the study objectives, the cockpit simulator, the features of each display format and the pilot tasks in flying the simulator was presented. Each pilot performed at least three practice runs with each display format to prevent the test evaluation from being influenced by his learning curve.

Each subject pilot flew the same random approach sequence of twenty-four experimental runs. Eight approaches were made with each of the three display formats. In each approach, one of two environmental conditions was simulated. The six unique display format/environmental condition run

combinations were repeated four times, Each pilot spent one day at the simulator. This was broken into a morning and afternoon session.

The experiment was flown from the left seat. The right seat was occupied by a test engineer familiar with the study project and general aircraft procedures. He acted as a copilot and provided customary callouts as requested by the subject during the pre-experiment briefing. In general, the callouts included: excessive localizer and glide slope deviations; descent rates greater than 1000 feet per minute; and, 100 ft. altitude levels at 500 ft. and below.

Eadh data run was intialized with the aircraft on localizer center with the required crab angle established, below the glide slope at an altitude of 364.8m (1200 ft) and at a range of 12771.1m (41,900 ft) from the glide slope transmitter. The aircraft was trimmed in level flight in its approach configuration with 150 knots airspeed, a 35° flap setting and the gear down. With an aircraft landing weight of 158,730 kg (350,000 lb) and a center of gravity at 18.5% mac, the trim angle of attack was 7 degrees.

Prior to run initiation all of the augmentation systems were engaged such that no mode selection was required after the run began. The pitch flight director was engaged in altitude hold with the glide slope mode armed for capture; the roll flight director was engaged in the localizer track mode; the yaw damper and autothrottle systems were on; and, the control wheel steering mode was engaged. The DC-10 control wheel steering provides the pilot with a stabilized attitude hold mode in the pitch and roll axes with no force on the control comumn and wheel, respectively. With force applied it results in pitch and roll rate commands to the control surfaces.

The first environmental condition consisted of a lateral and longitudinal wind shear. This condition is designated as FAA wind profile B6, and is characterized by the data shown in Table 1. Below 152.4m (500 ft), the laterla wind profile exceeds the capability of the DC-10's autopilot/flight director control laws to maintain the aircraft within acceptable deviations from the localizer center. Lateral offsets of up to 27.4m (90 ft) were experienced as a norm, due to the cross wind shear of 16.1 knots per 30.48m (100 ft) between 152.4m (500 ft) and 121.9m (400 ft) of altitude. The longitudinal headwinds approach the outside limits expected of a pilot when controlling the aircraft through the flight director. Headwind shears of 18.7 knots per 30.48m (100 ft) are experienced between 121.92 (100 ft) and 60.96m (200 ft) of altitude which can result in excessive glide slope deviations.

The second environmental condition consisted of wind shears and turbulence in the lateral, longitudinal, and vertical axes. This condition is designated as FAA wind profile B7 with NASA/SRI turbulence and is

characterized by the data shown in Table 2. Although controllable by the autopilot, the resultant wind profiles in the longitudinal and vertical axis appear to be outside the limits expected of a pilot to maintain the glide slope when controlling the aircraft via the flight director. The lateral wind profile, however, is within the limits expected of a pilot to maintain the aircraft within acceptable deviations from the localizer center.

TEST DATA ANALYSIS

Selected data parameters were recorded twice per second. These included glide slope and localizer deviation, pilot wheel and column inputs, and flight director roll and pitch command bar signals. At a 150 knot approach speed, this data was recorded at approximately every 38.1m (125 ft) of airplane travel.

Pilot comments were recorded during each run, after each run, and during a debriefing after each session in the simulator. The subject pilots' opinions are summarized in the section "Results and Discussion".

Data sampled from three windows along the task profile were statistically treated and analyzed. The first window (W1) was chosen to examine performance in intercepting and transitioning to the glide slope beam, in the presence of moderate wind profiles. The second window (W2) was chosen to examine the performance in tracking the localizer and glide slope beams, in the presence of moderate wind profiles. The third window (W3) was chosen to examine the performance in tracking the localizer and glide slope beams, in the presence of moderate wind profiles. The third window (W3) was chosen to examine the performance in tracking the localizer and glide slope beams, in the presence of severe wind profiles. These windows are shown graphically in Figure 8.

From the data parameters the RMS mean ($\bar{x}$) and the standard deviation (S) for each window, display format and test subject were calculated and the standard deviation was examined in an analysis of variance process (See reference 3). More specifically, an RMS of the measure was determined across each window, then all repeats of similar conditions (pilot, window, shear condition) were grouped to form a single mean and standard deviation for table and figure presentation. Each individual RMS value was used in the analysis of variance test. The test was conducted with regard to treatments of pilots, windows, display formats and their interactions. The significance of the analysis of variance was determined by the use of an F-test table.

RESULTS AND DISCUSSION

The results of the test data analysis are shown in Figures 9 through 24 and Tables 3 through 26. Each figure depicts the mean and standard deviation for a specific data parameter an RMS measure and pilot, within each of the three windows. The tables summarize the analysis of variance performed on each of the parameters and provide comparisons of the means and standard deviations for each parameter with respect to the four pilots. During the data collection process two data runs were lost for FAA wind profile B6. Since each data run includes three windows of datapoints, a total of six RMS values are missing from the analytical results. This anomaly is reflected in the analysis of variance summary tables for each data parameter.

In general, the lateral and vertical tracking performance was good in the upper two windows of the task profile but poor in window 3 from 500 feet to 100 feet of altitude. This poor performance was not attributable to any of the displays or pilots, but instead was a direct result of the severe winds imposed in window 3. The simulated wind shears were greater than those specified by the FAA for measuring Category II performance and were beyond the capability of the DC-10's ILS control laws. Although not a part of the study, autopilot coupled approaches flown for each of the wind conditions resulted in deviations at 100 feet which were outside the Category II limits. A general consensus of pilot comments indicated that most of the 24 approaches would have been aborted between 300 feet of altitude and 100 feet due to excessive glide slope deviations, localizer deviations or descent rates.

The analysis of variance showed that the pilot was significant at the 99% level for all of the data parameters and for both environmental conditions. The window treatment was also significant at the 99% level for all longitudinal parameters. This was not true for localizer deviation, control wheel position, and roll flight director commands during wind profile B7. These parameters were significant only at the 95% level for B7. The pilot significance is partially attributed to the difficulty encountered by one pilot (B) in flying the cross-pointer flight director commands. He had never flown these before. The window significance is definitely due to the fact that the shears initiated during window 3 resulted in larger deviations from the flight path, larger errors in following the flight director commands and much higher workloads than those experienced in windows 1 and 2.

With regard to the glide slope devistion analysis, the displays were significant at the 95% level for B6 and at 99% for B7. For B6, three of the four pilots performed better in window 3 with display format 3, and the other (pilot C) did better with display 2. Both of these formats include flight path angle symbology. For B7, which was the more severe longitudinal/vertical shear, there was very little difference for three of the four

pilots with respect to the display formats; however, one pilot (B) did much worse with the third display. In the first two windows very little difference in glide slope performance existed between display formats. Pilot comments supported these results to the extent that three of the four subjects felt that the flight path angle "V" in display format 3 provided significant improvement in glide slope tracking. None of the pilots, however, rated display 2 better than fair in improving their performance. Their general comment was that they did not "see" the wedges except when moving laterally as a function of drift angle.

In terms of following the pitch flight director commands, the displays were significant at the 95% level for both B6 and B7. No consistent display preference, however, was discernable from the mean and standard deviation data. Based on a dlight director bar width of 0.06 cm, the typical RMS mean values recorded for the task profile were between one and two bar widths.

With regard to the localizer deviation analysis, the display treatment was significant at the 95% level for wind profile B6 and the pilot/display interaction was significant at the 99% level for B7. For B6, a review of the mean and standard deviation data indicated similar performance with respect to all three displays for the first two windows. In window 3, a larger difference was noted. Although one of the pilots performed best with display format 2, three of the four pilots had greater problems when flying display 2. This format provides drift angle information via the lateral motion of the flight path wedges. All pilots felt that display 2 provided a good indication of lateral wind shear and that it improved their localizer tracking performance. It should be noted that the pilot who performed best with this additional information played down its importance by commenting that the same information was available on the horizontal situation indicator. For B7, the pilot/display interaction significance can be attributed to the fact that two pilots tended to track the localizer better with display 1 and two tended to track the localizer better with display 1 and two tended to perform better with display 3.

In terms of following the roll flight director commands, no display related significance was noted at the 99% or 95% levels for B6 and only a 95% level significance for the pilot/display interaction occurred for B7. This was directly associated with the localizer tracking performance described above.

Based on the measured data for wheel and column motion, there was no display related significance with regard to pilot workload. This data was supported by pilot commentary which, in general, revealed no benefits in this area.

Overall, based on the recorded data, no display format was consistently superior for either glide slope or localizer performance or for reducing pilot workload. In general, the pilot who followed the flight director command bars best (the bars were common to all formats), performed best.

Other pilot comments obtained during and after the experiment indicated that: (1) the flight director command reference box in the center of the EADI is too small; (2) the expanded localizer deviation scale at the bottom of the EADI is too sensitive with a full scale of $\pm$/2 dot; and, (3) a single cue presentation would be more acceptable to these specific pilots than a crosspointer flight director.

CONCLUDING REMARKS

The results of this experiment show that during flight director instruemt approaches: (1) the addition of flight path symbology to a typical transport electronic-attitude-director-indicator does not appreciably influence glide slope tracking performance, but it does provide an indication of longitudinal/vertical wind shear if properly integrated into the overall display format; (2) the addition of drift angle on the EADI does not assist localizer tracking performance, but it does provide a good indication of lateral wind shear; (3) the "wedges" of display format 2 do not provide a good indication of flight path angle or longitudinal/vertical wind shear because they tend to "disappear" from the pilot's scan area. They do, however, provide valuable lateral information as they move across the screen as a function of drift angle diromg a lateral wind shear. During these conditions they are very visable. (4) the "V" symbol of display format 3 provides a good indication of flight path angle and longitudinal/vertical wind shear conditions. Because it is centralized on the EADI, it is not lost during high workload conditions. It does not, however, provide any lateral indication of a changing wind.

Overall, flight path information is desirable on an EADI if integrated correctly. It is useful as an approach monitor and as a source of changing wind conditions. For autopilot approaches, display format 2 may be a possible solution; however, this display is not suitable for flight director approaches. Display format 3, on the other hand, appears to be useable for both autopilot and flight director approaches; however, it is completely deficient in providing lateral wind information. An integrated display of flight path information requires a combination of the good traits of formats 2 and 3.

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3. Steel, Robert g.; and Torrie, J. H.; Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., C. 1973.

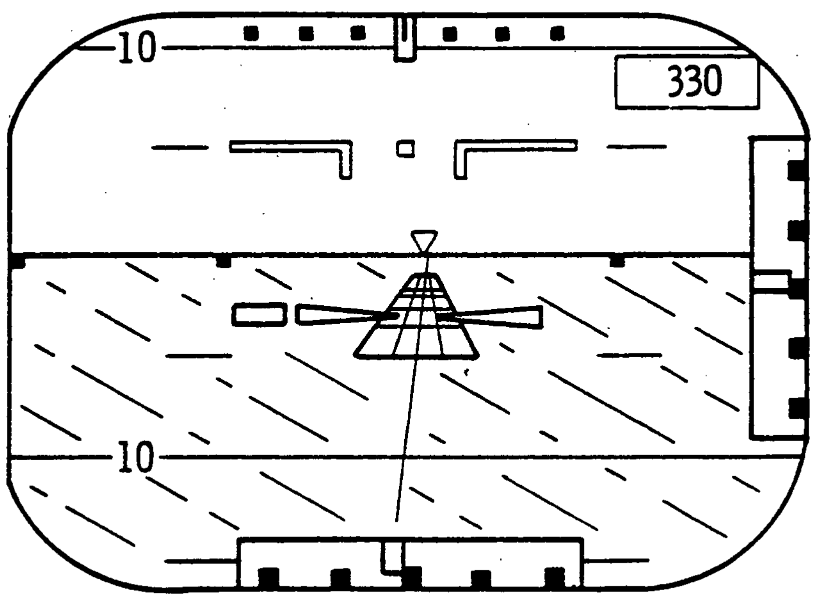

FIGURE 1 NASA TCV INTEGRATED SITUATION DISPLAY FORMAT

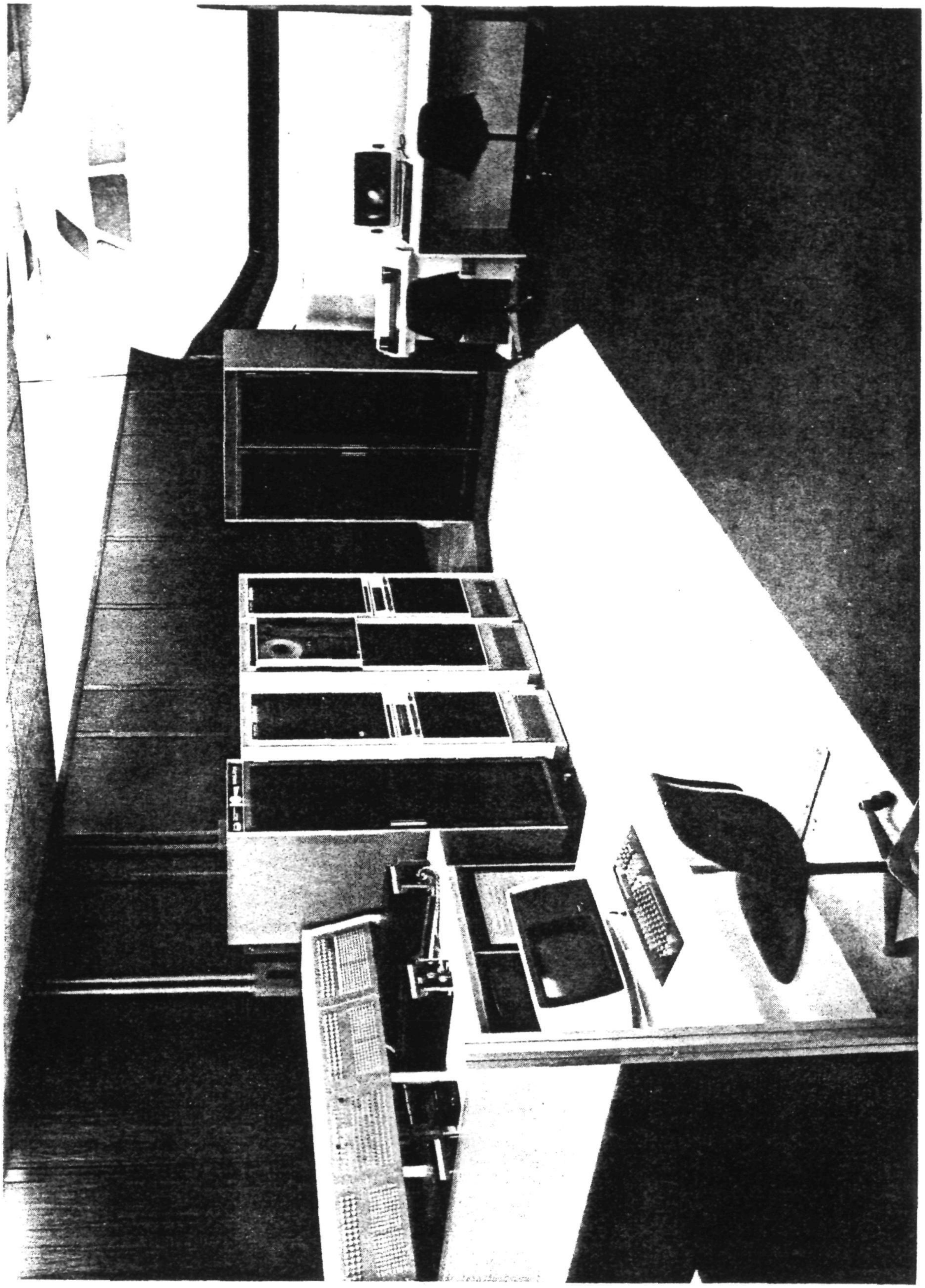

FIGURE 2 TRANSPORT SIMULATOR FACILITY

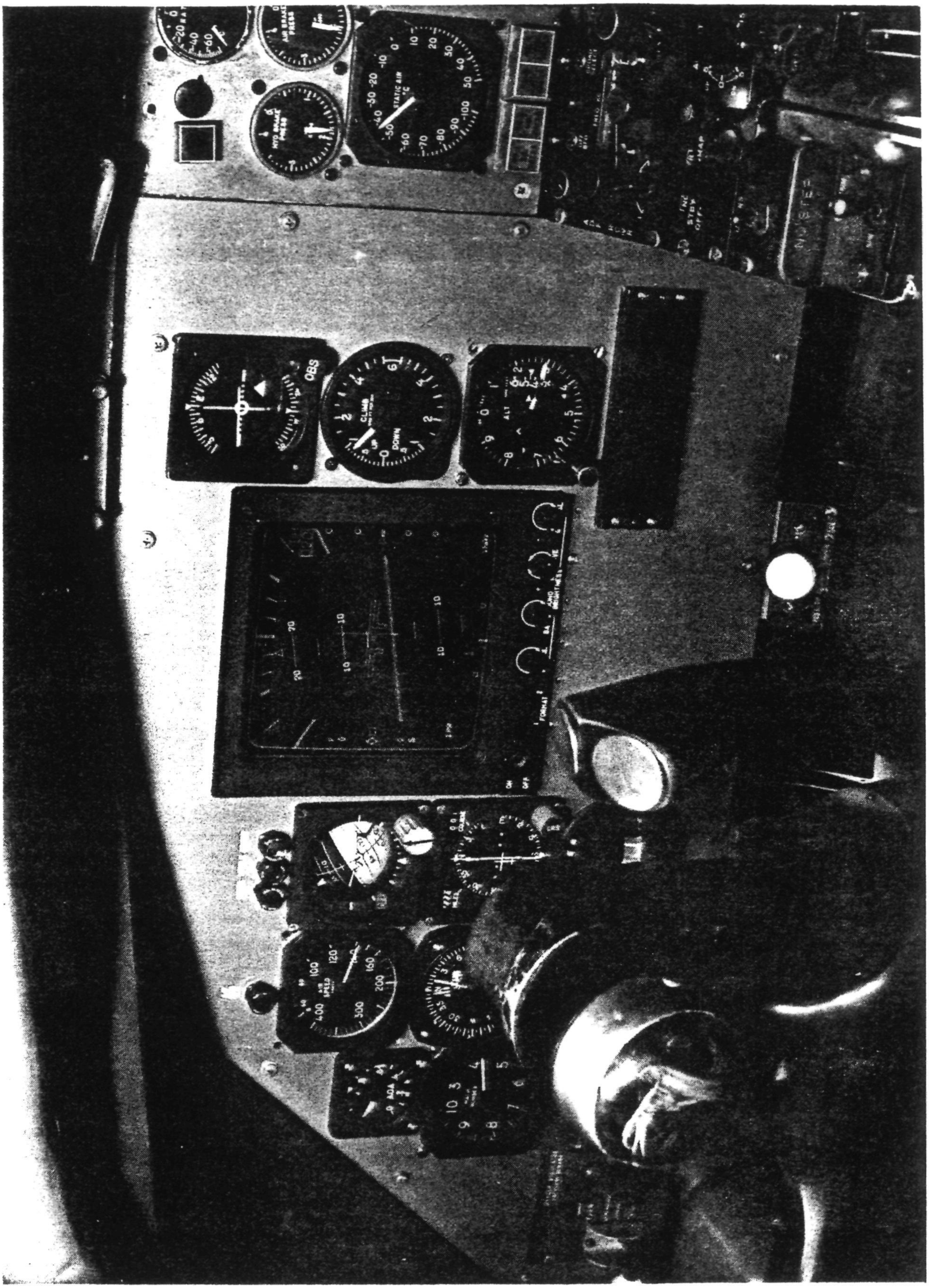

FIGURE 3 PILOT'S INSTRUMENT PANEL

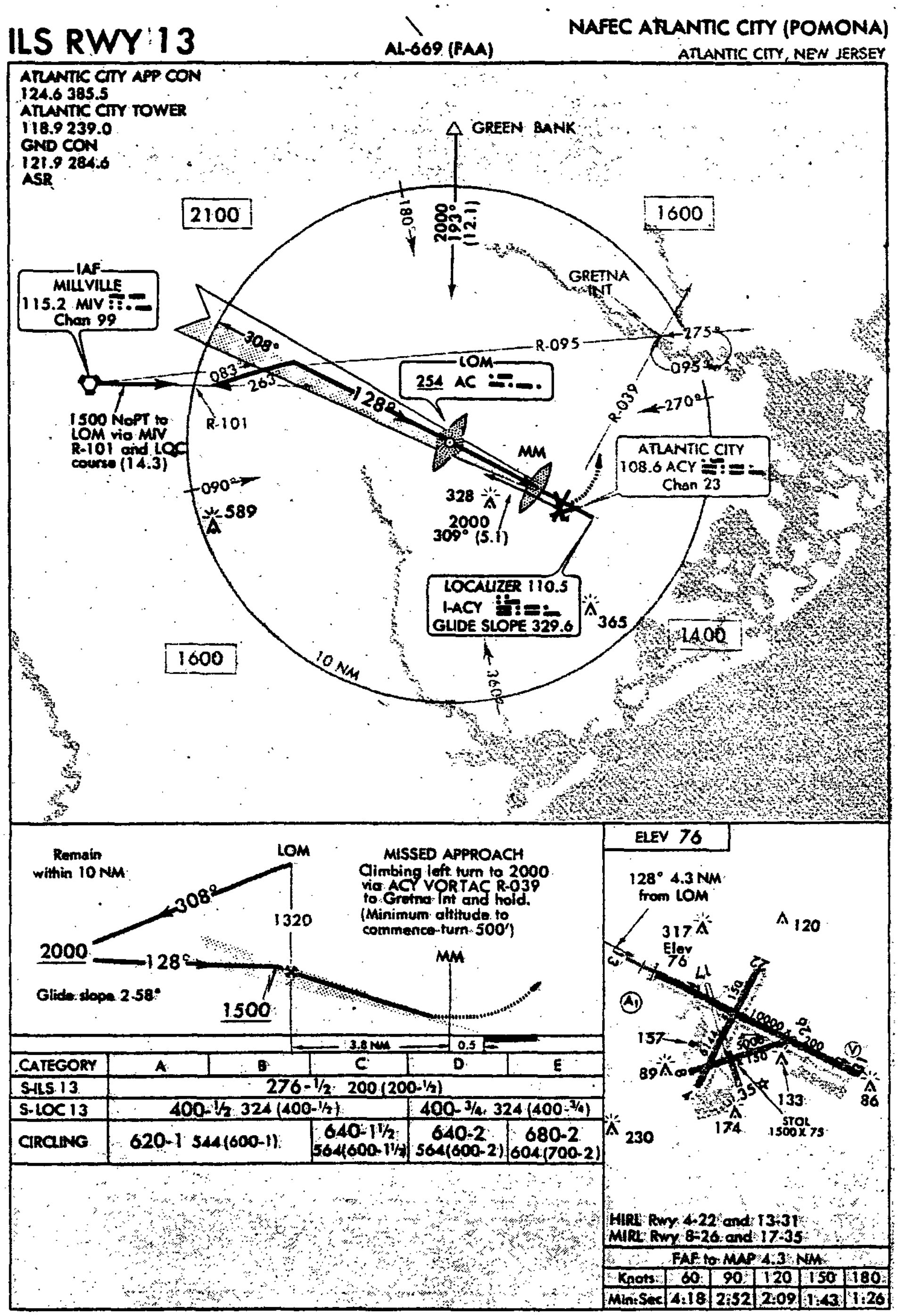

FIGURE 4   RUNWAY 13-31   FAA TECHNICAL CENTER   ATLANTIC CITY

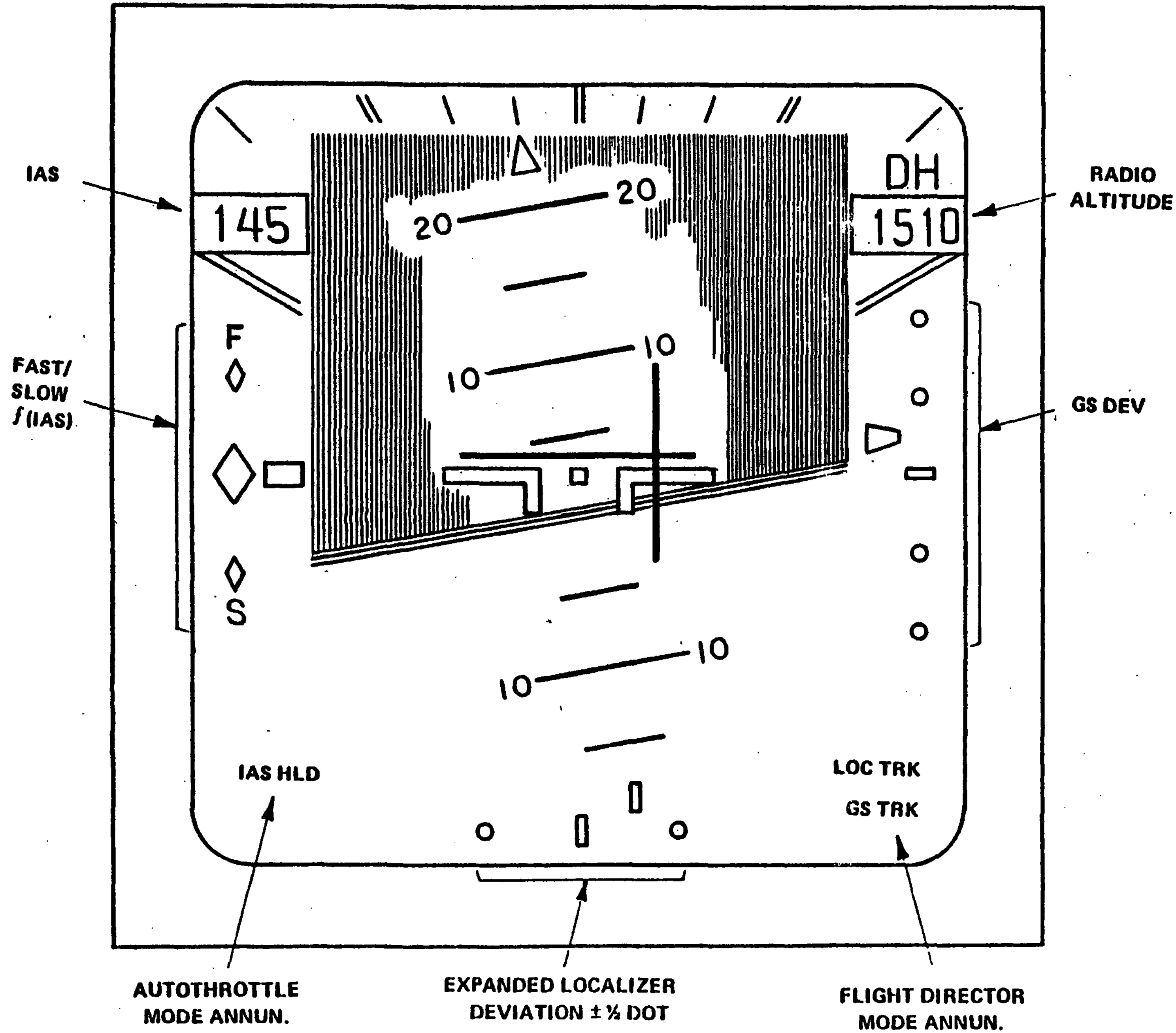

FIGURE 5 EADI DISPLAY FORMAT 1

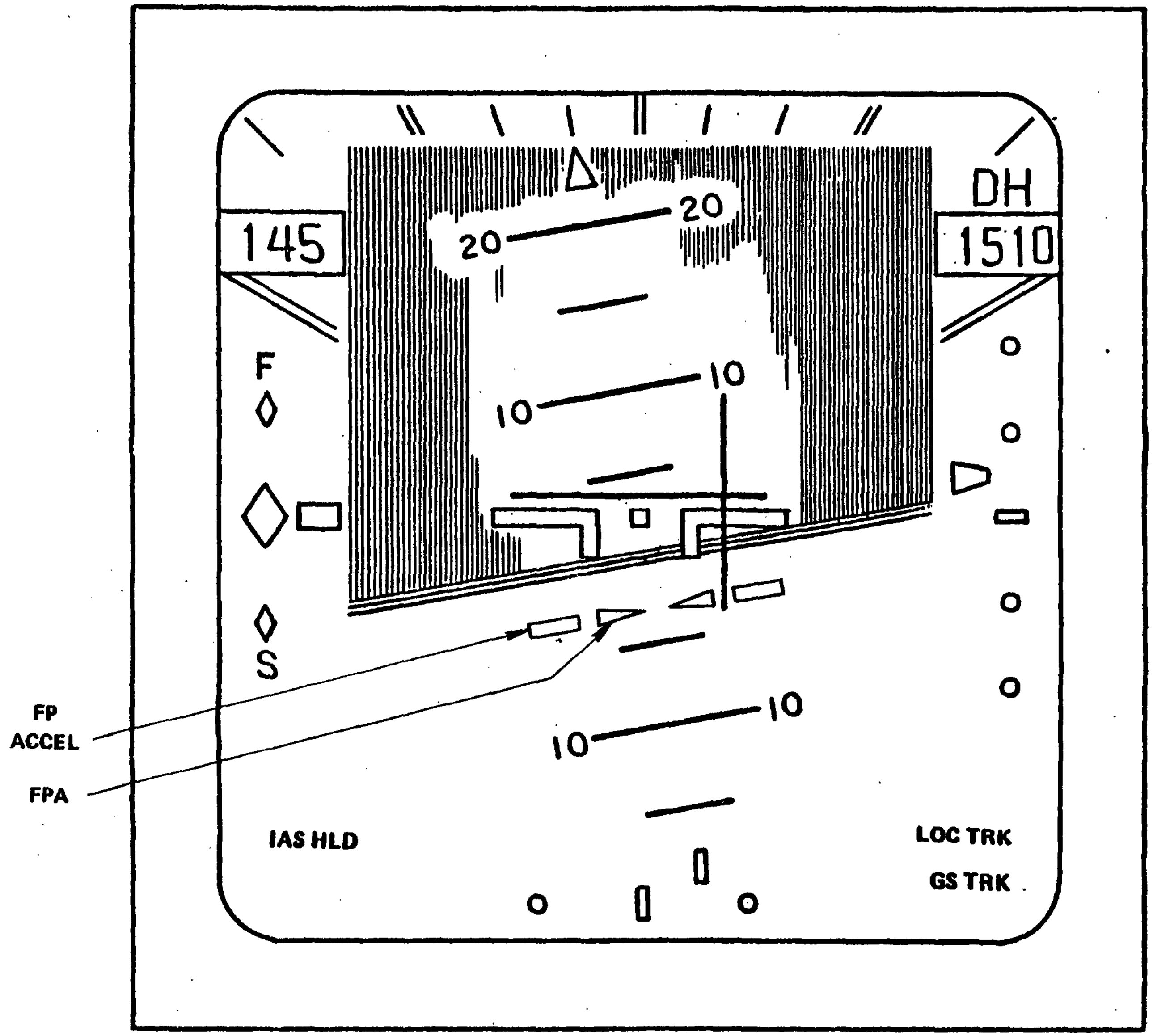

FIGURE 6 EADI DISPLAY FORMAT 2

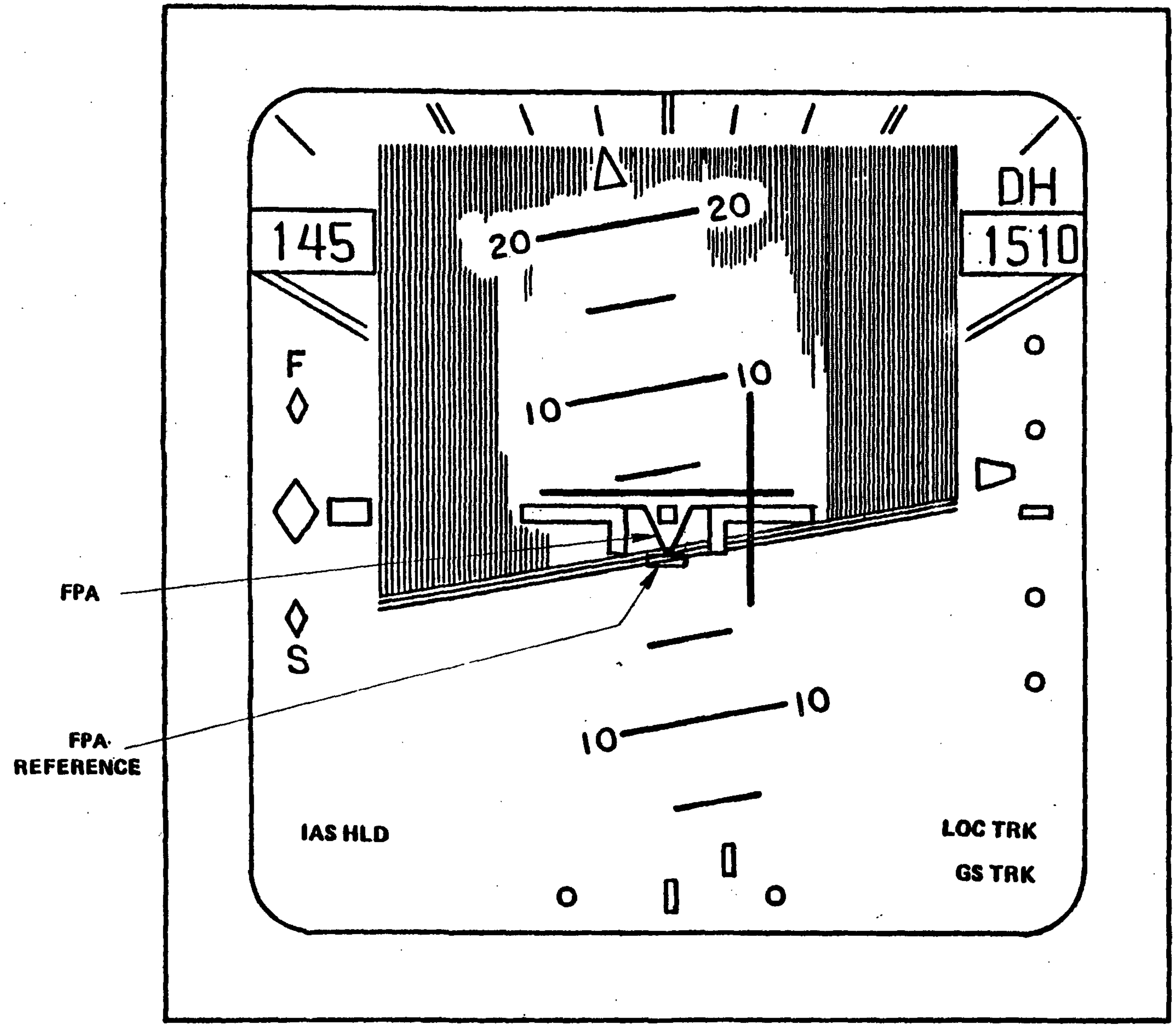

FIGURE 7 EADI DISPLAY FORMAT 3

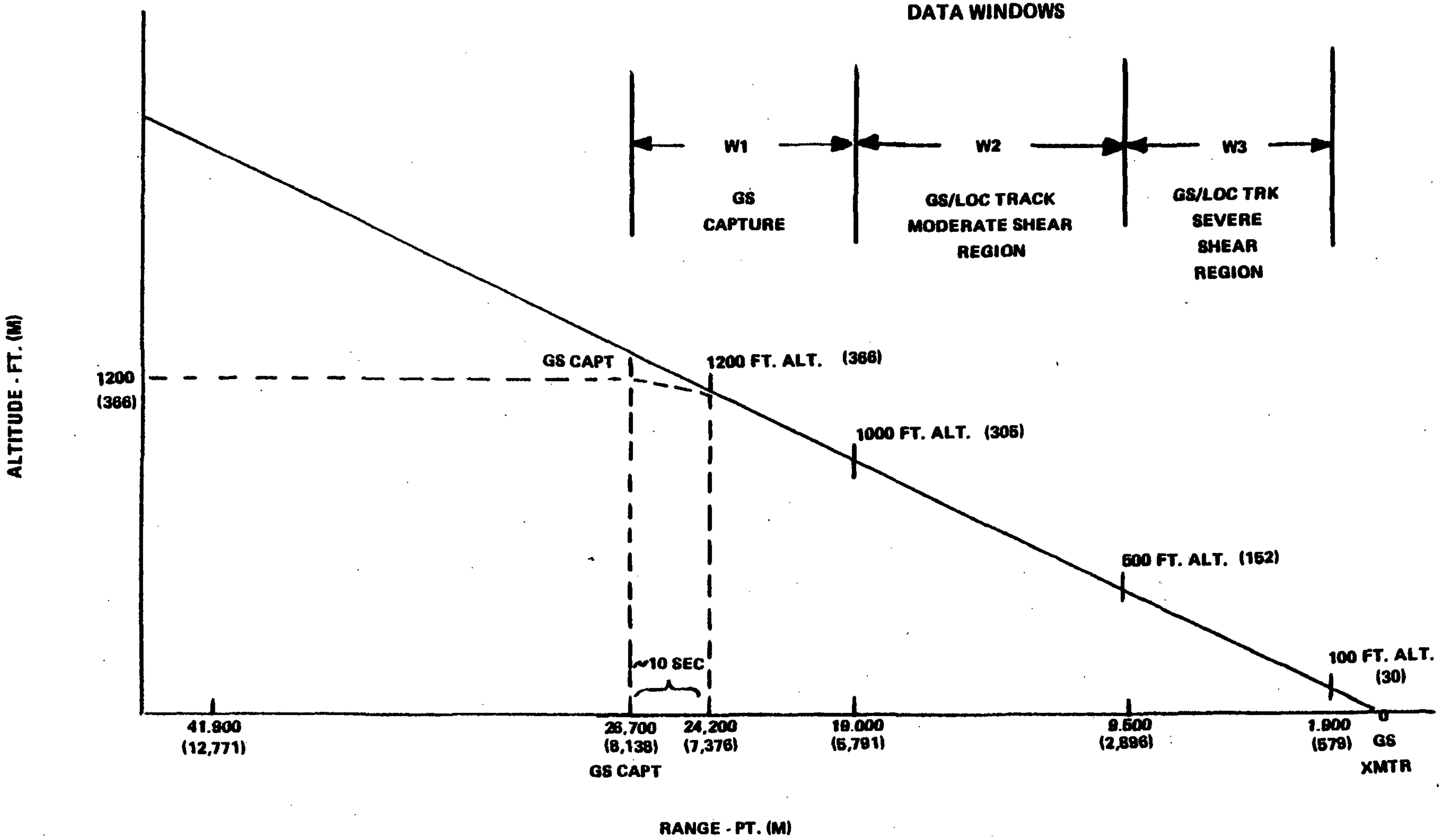

FIGURE 8 EXPERIMENTAL TASK PROFILE AND DATA ANALYSIS WINDOW LOCATIONS

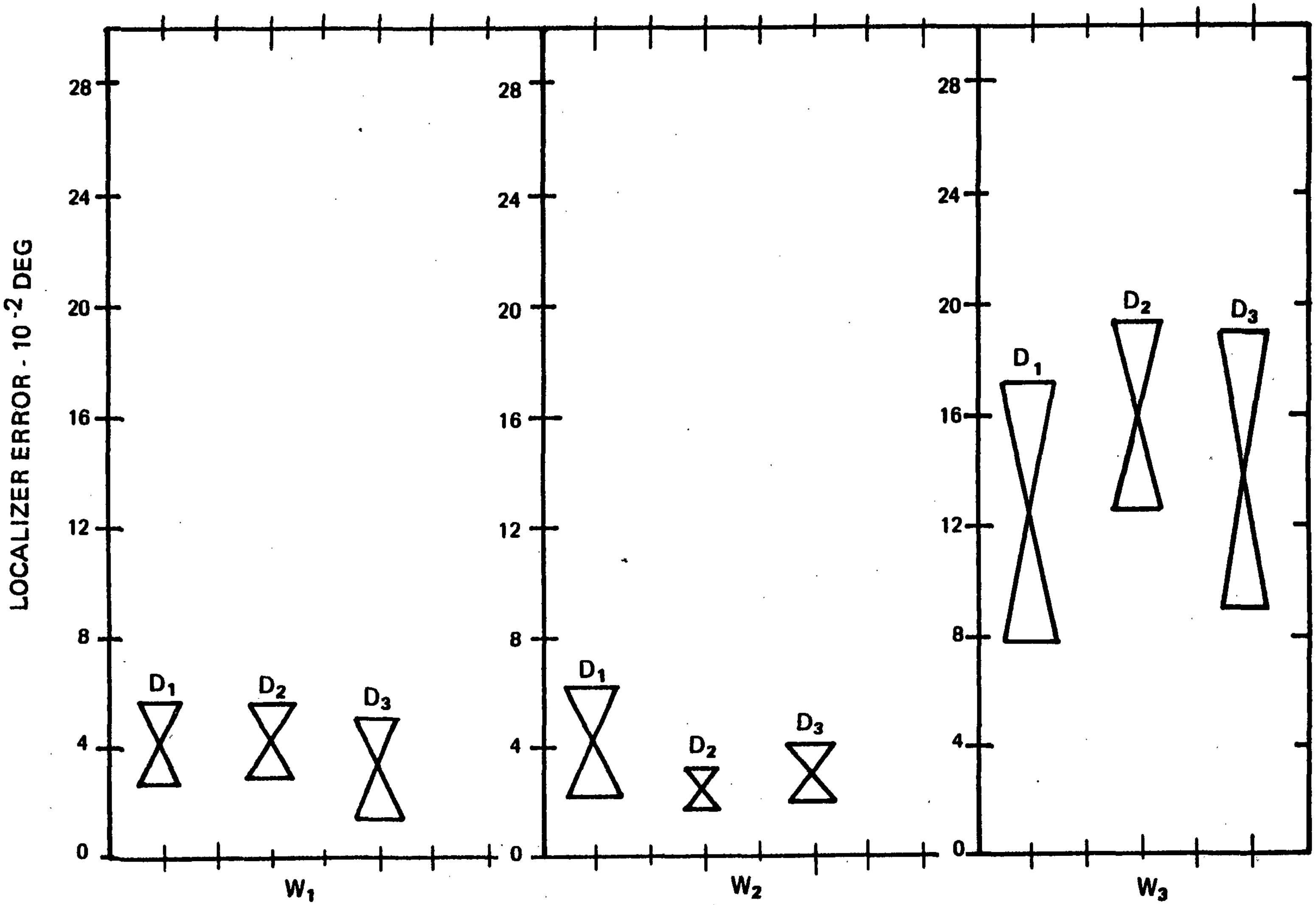

FIGURE 9 PILOT A LOCALIZER MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B6

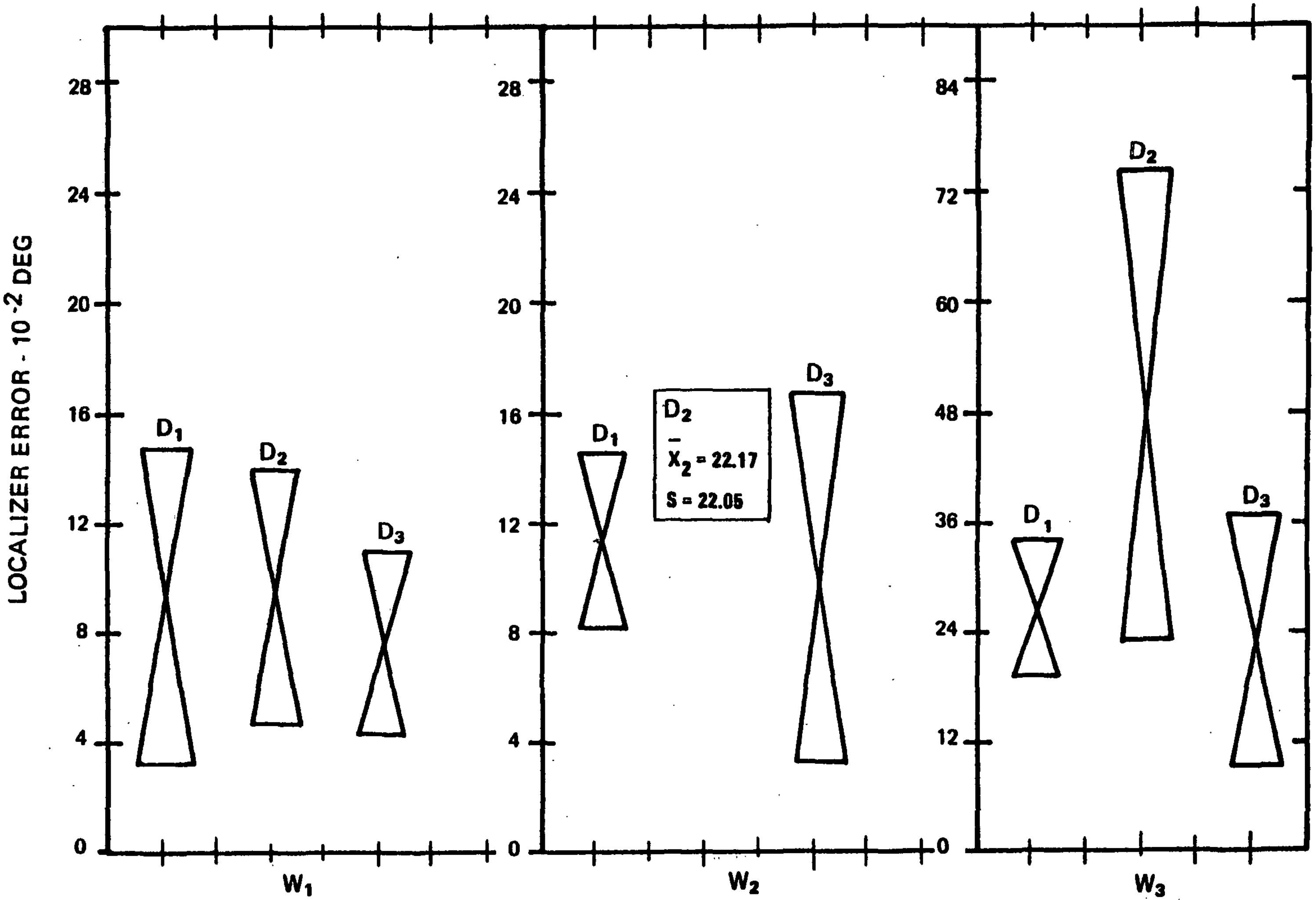

FIGURE 10 PILOT B LOCALIZER MEAN AND STANDARD DEVIATION FOR WIND PROFILE B6

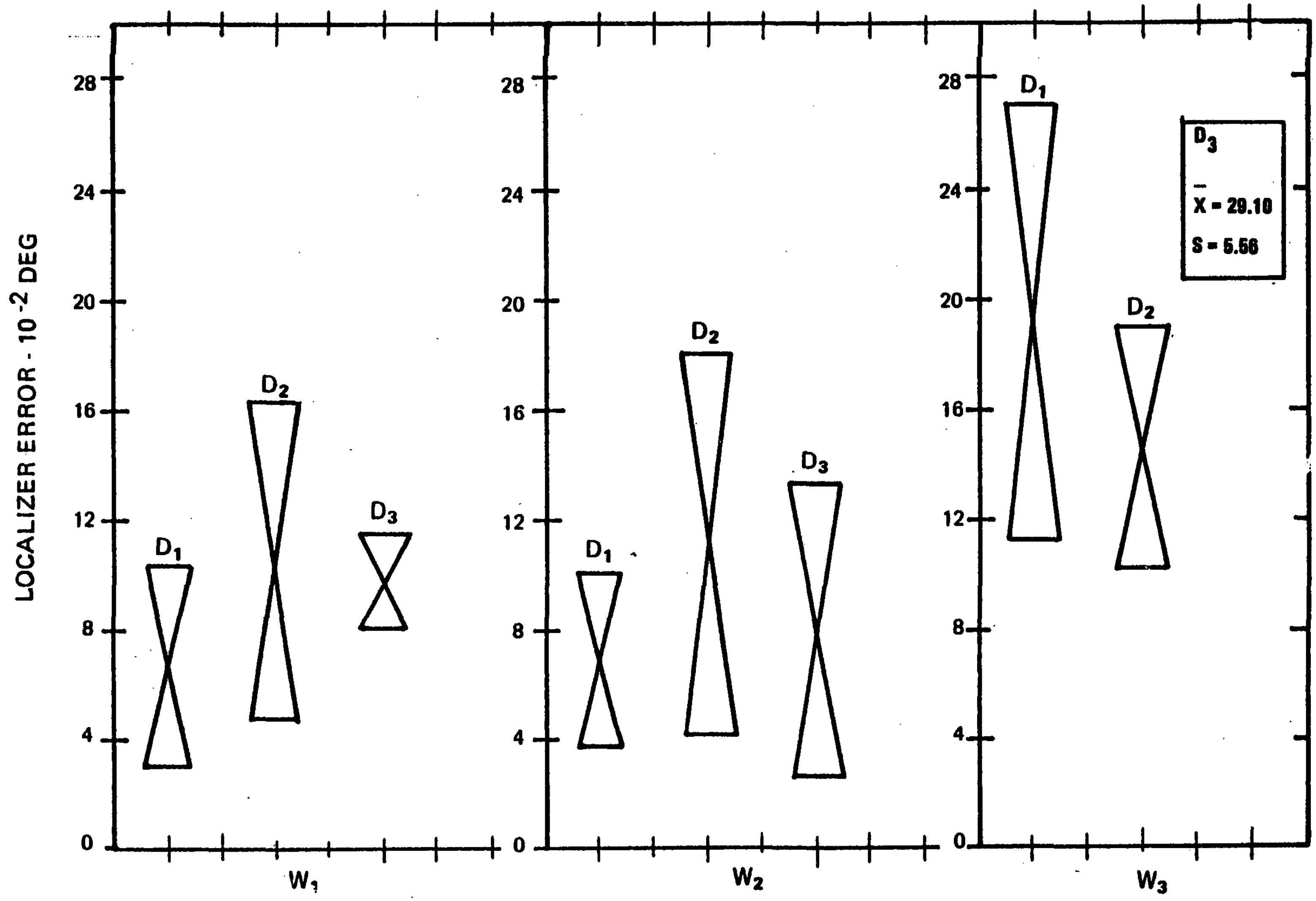

FIGURE 11 PILOT C LOCALIZER MEAN AND STANDARD DEVIATION FOR WIND PROFILE B6

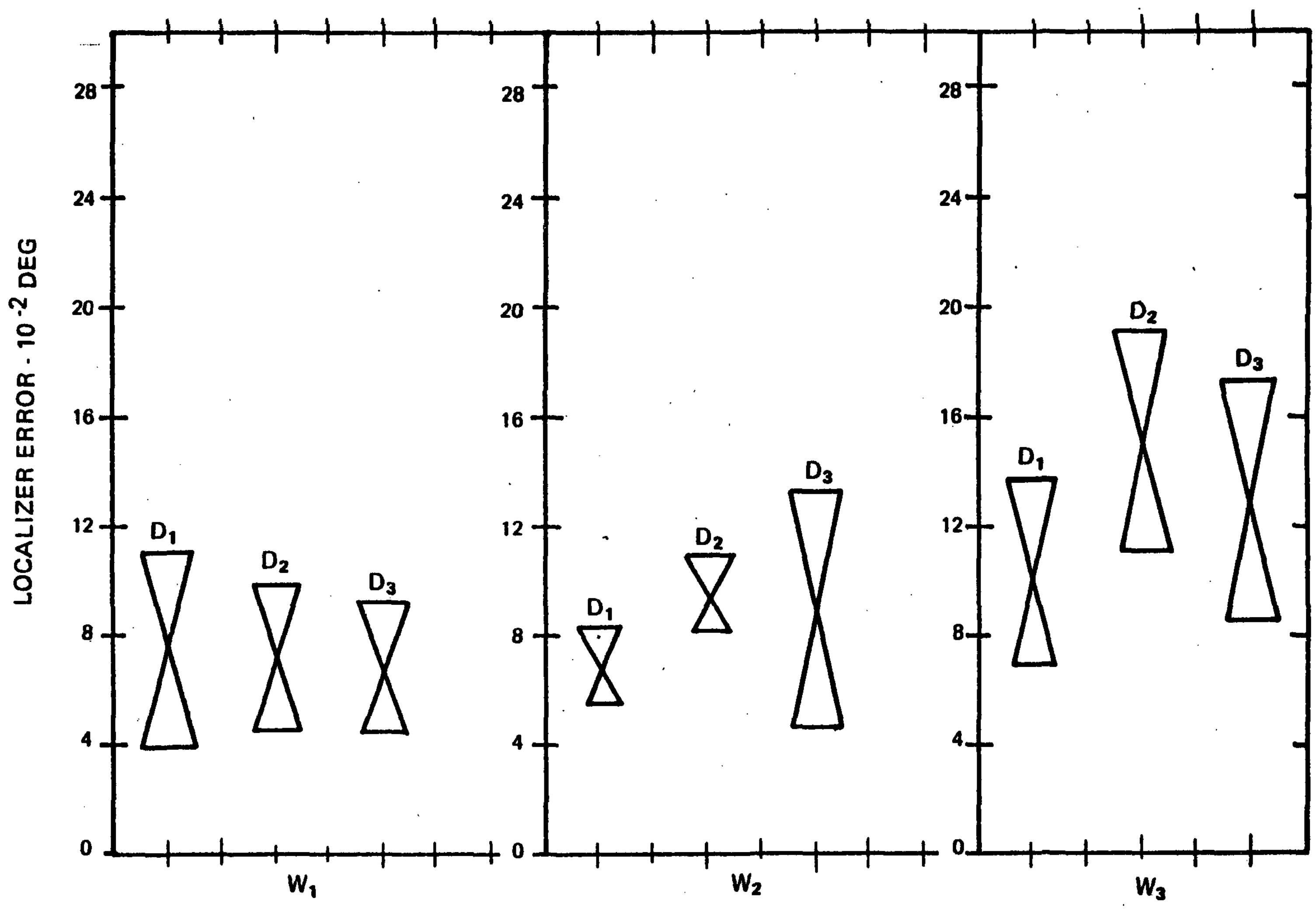

FIGURE 12 PILOT D LOCALIZER MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B6

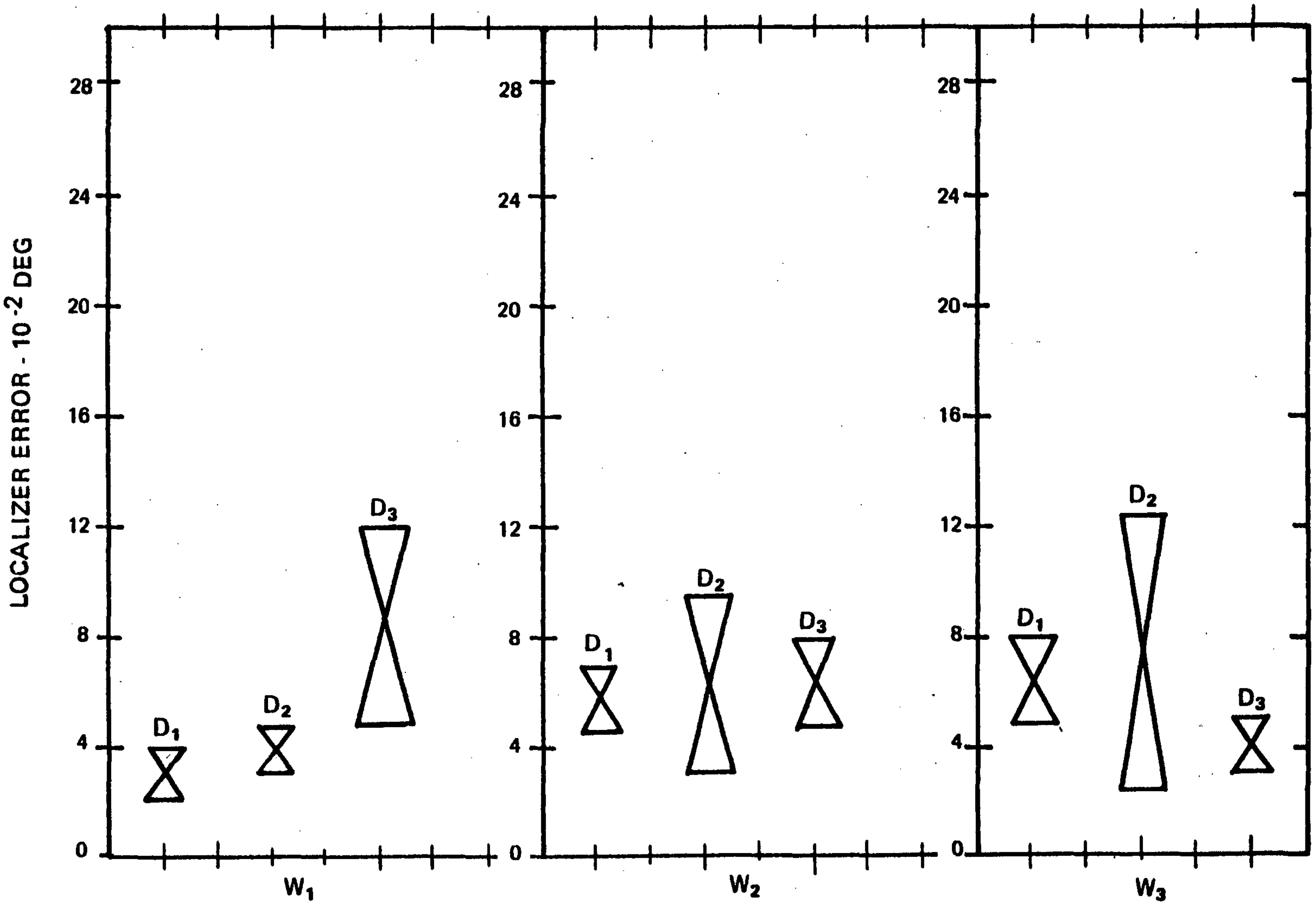

FIGURE 13 PILOT A LOCALIZER MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

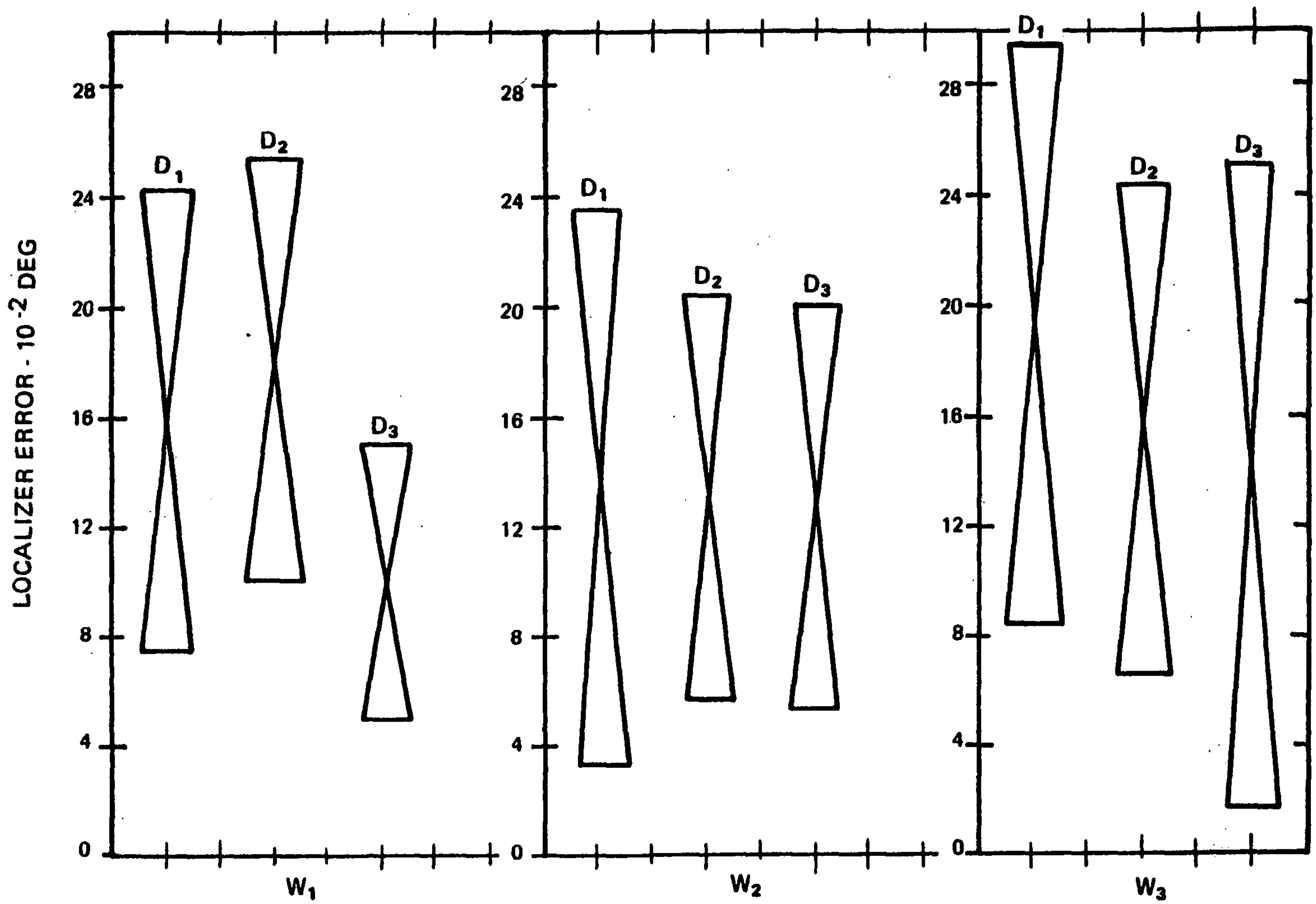

FIGURE 14 PILOT B LOCALIZER MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

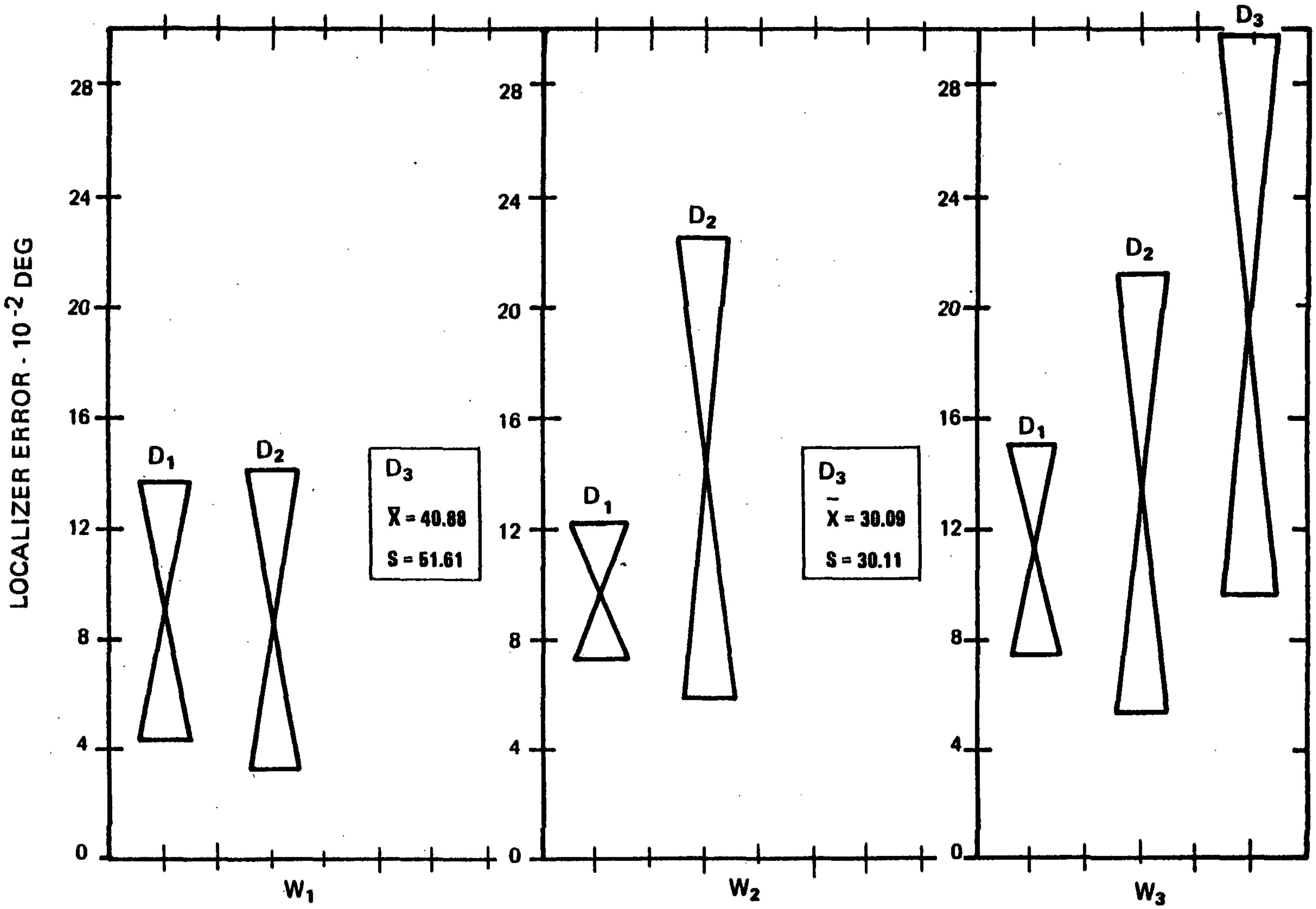

FIGURE 15 PILOT C LOCALIZER MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

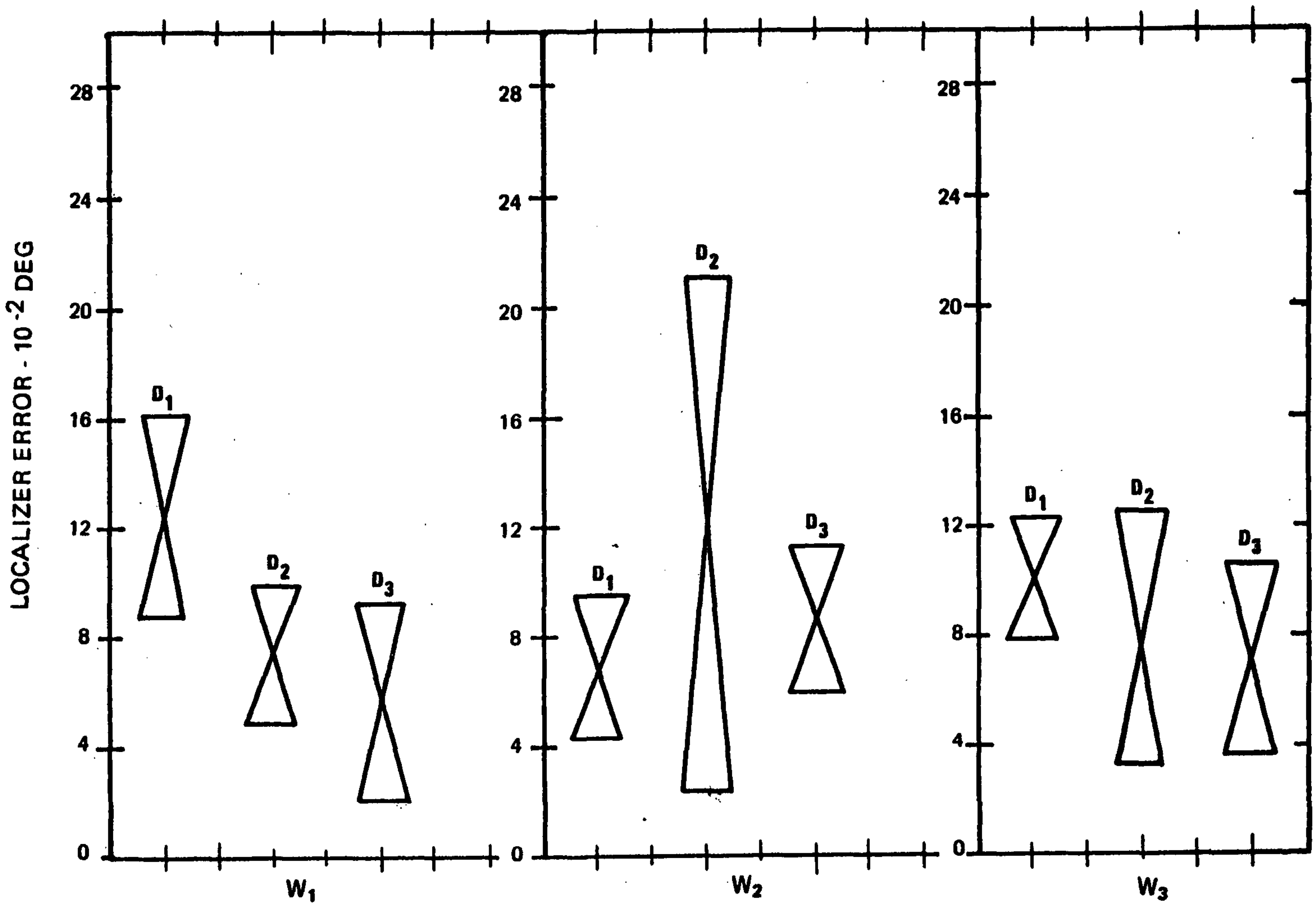

FIGURE 16 PILOT D LOCALIZER MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

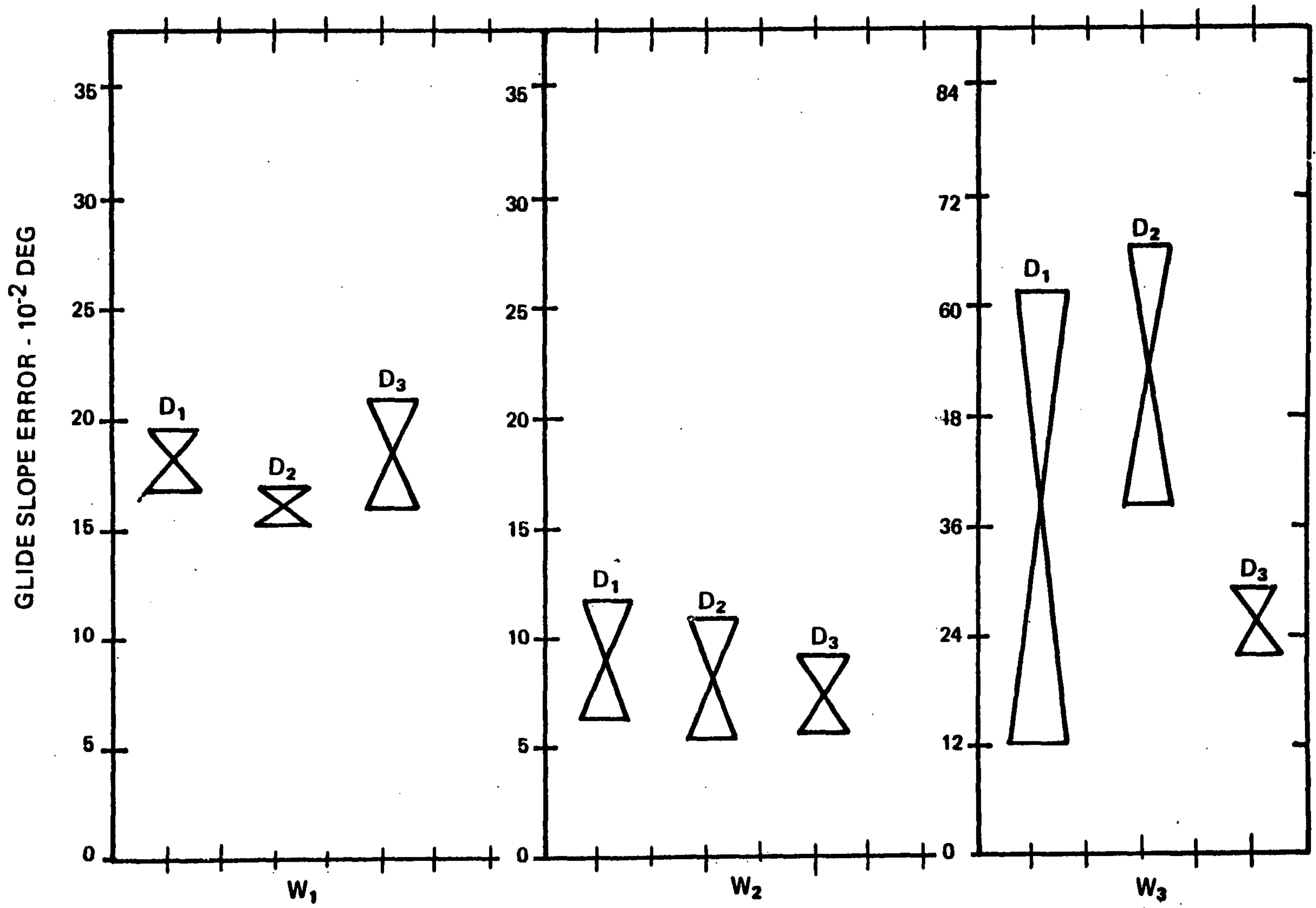

FIGURE 17 PILOT A GLIDE SLOPE MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B6

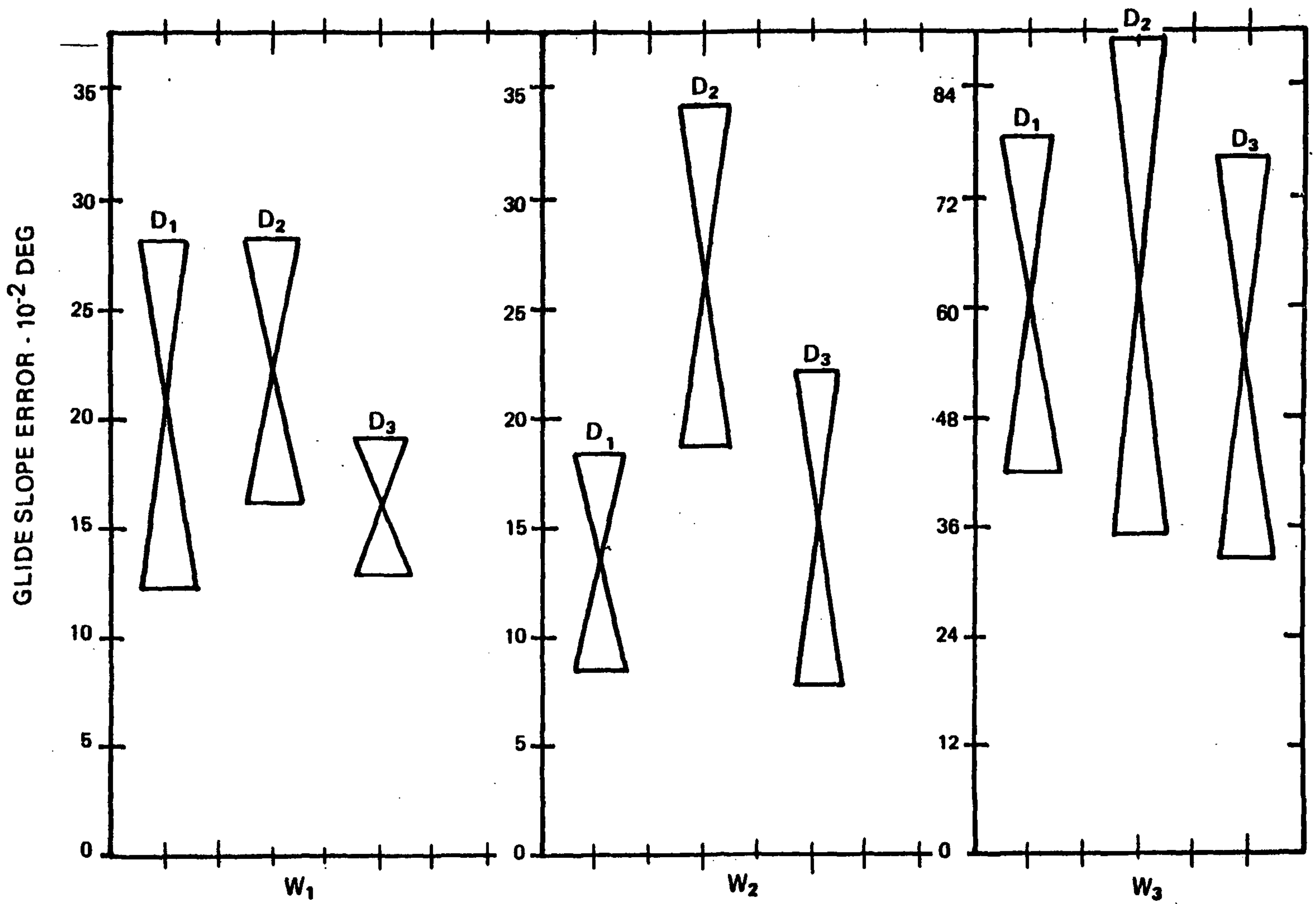

FIGURE 18 PILOT B GLIDE SLOPE MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

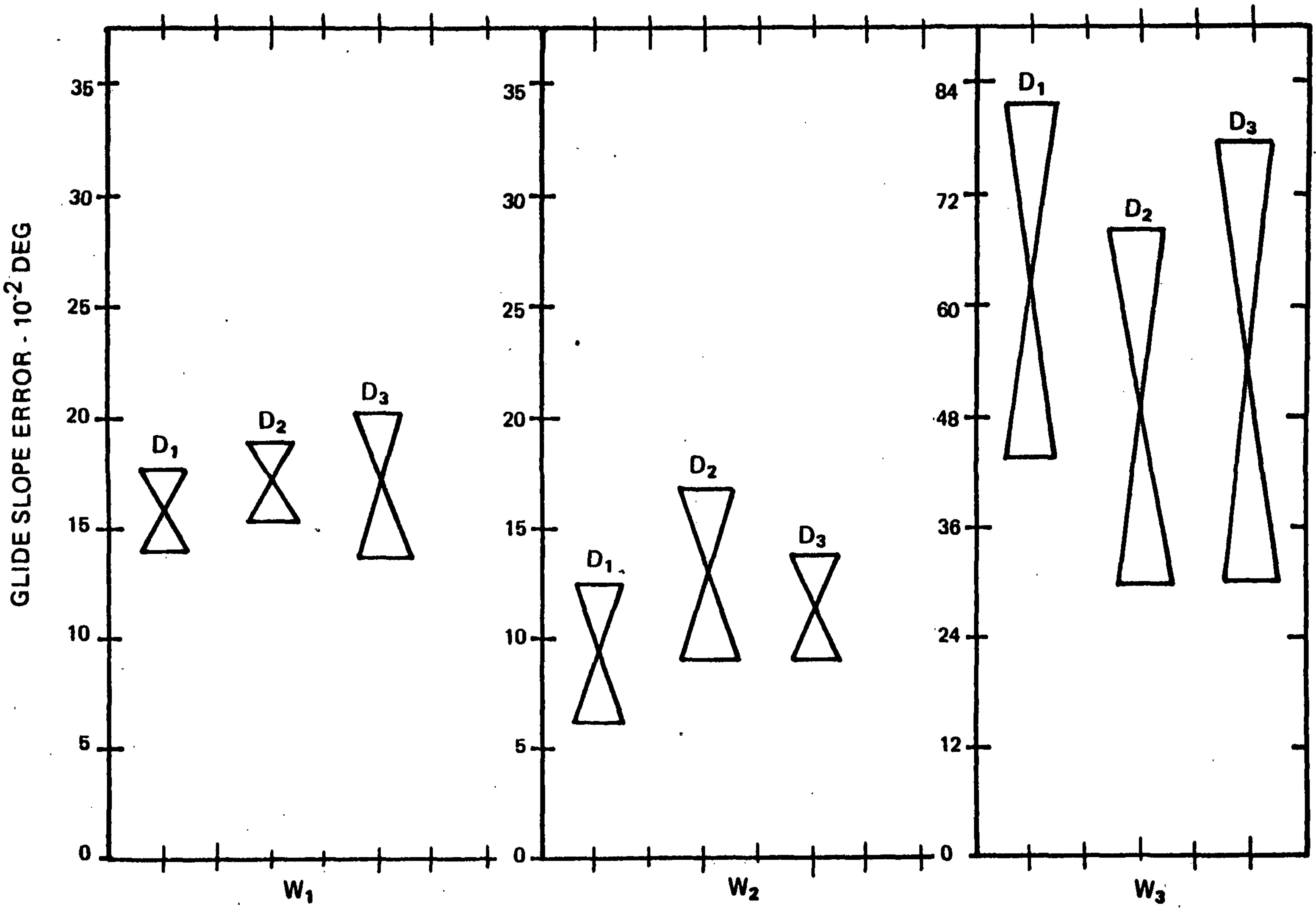

FIGURE 19 PILOT C GLIDE SLOPE MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

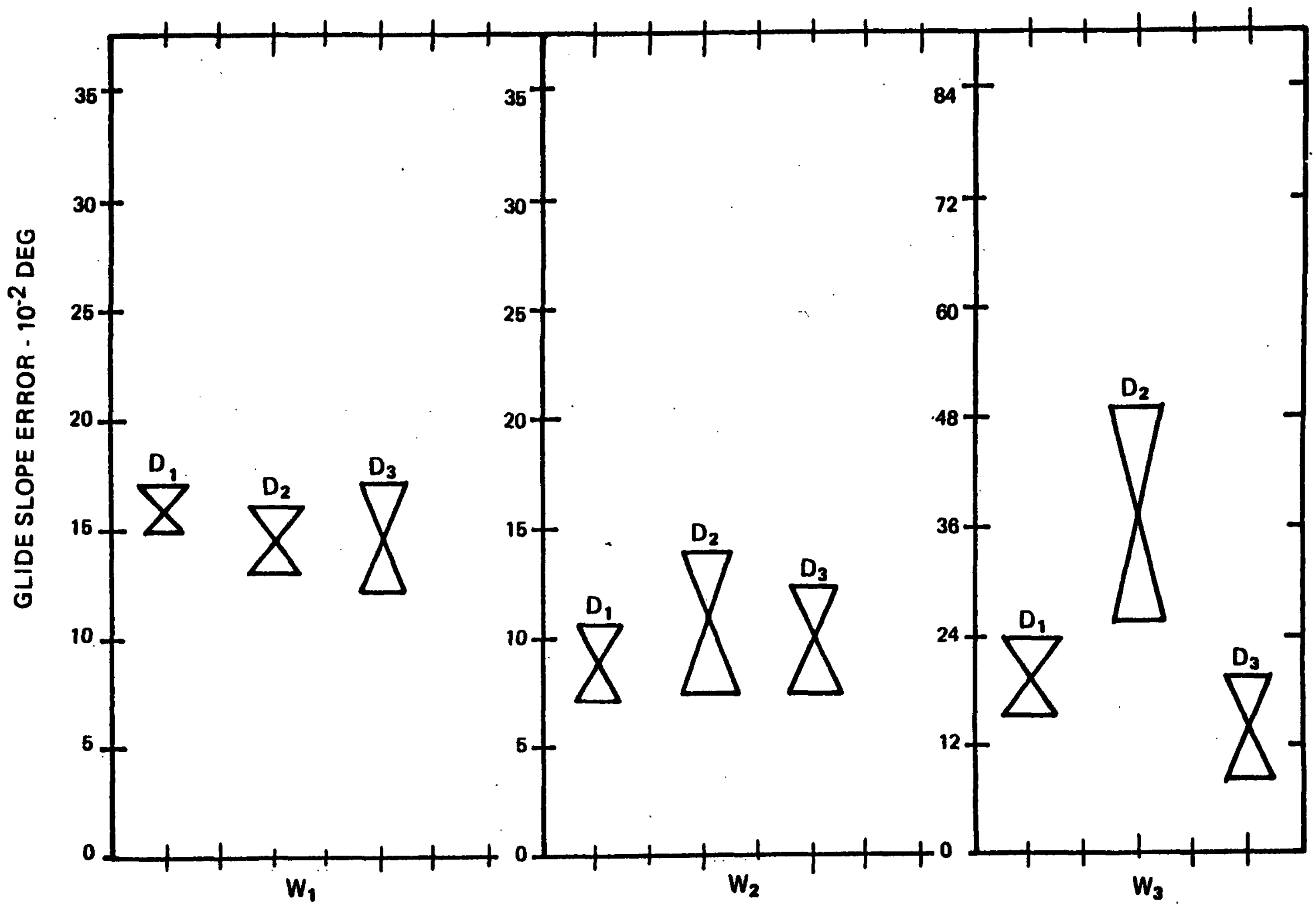

FIGURE 20 PILOT D GLIDE SLOPE MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

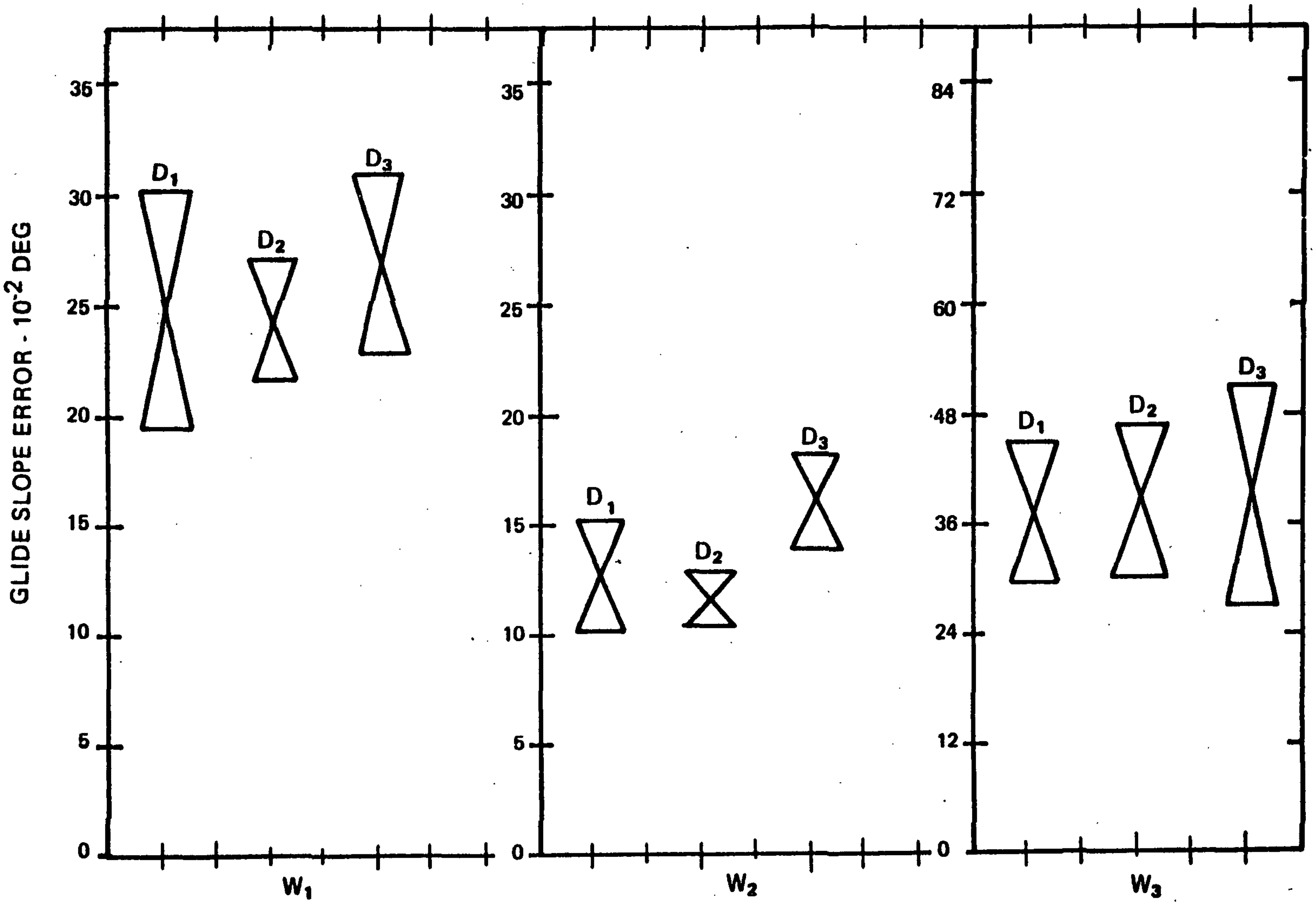

FIGURE 21 PILOT A GLIDE SLOPE MEAN AND STANDARD DEVIATION FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

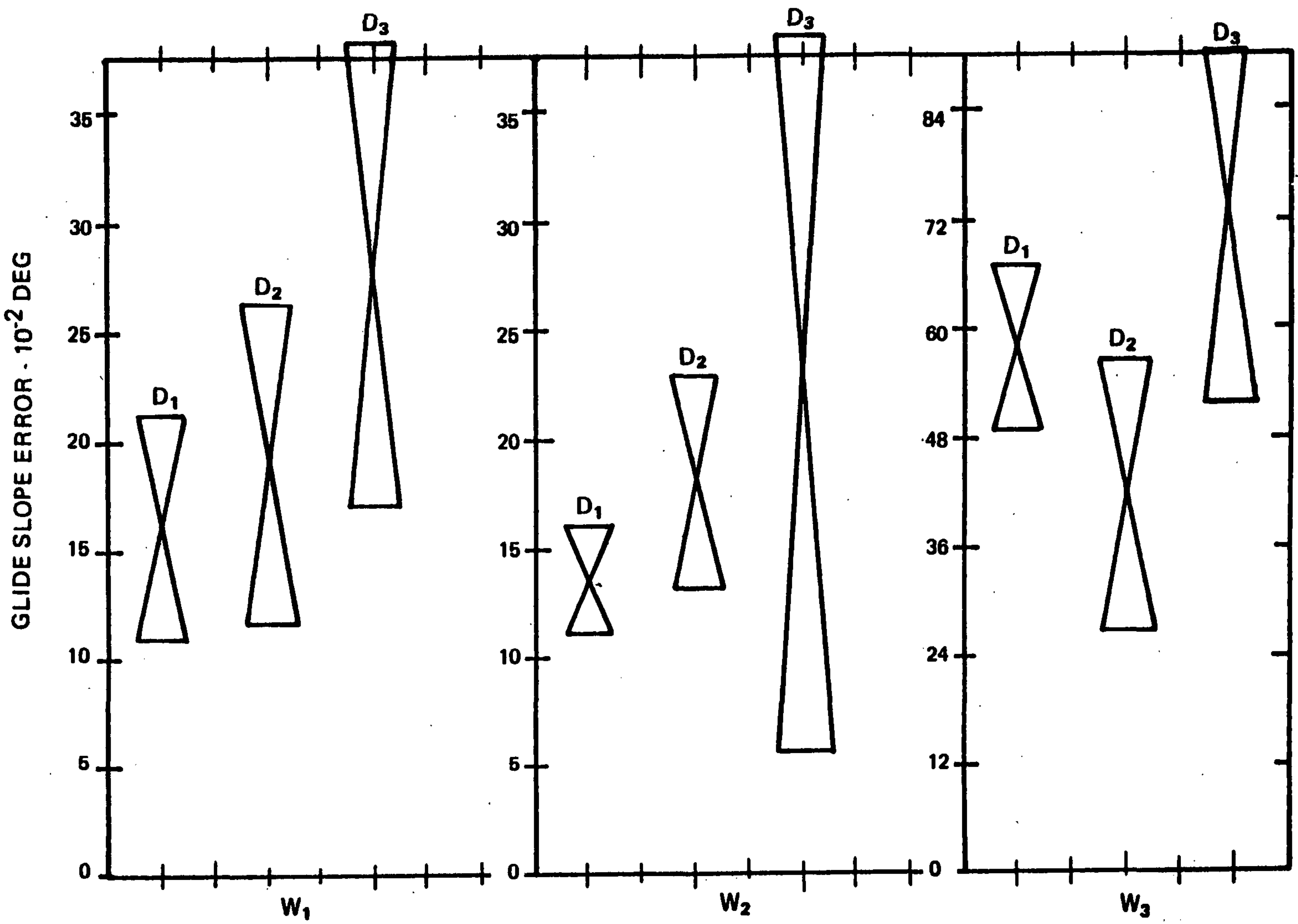

FIGURE 22 PILOT B GLIDE SLOPE MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

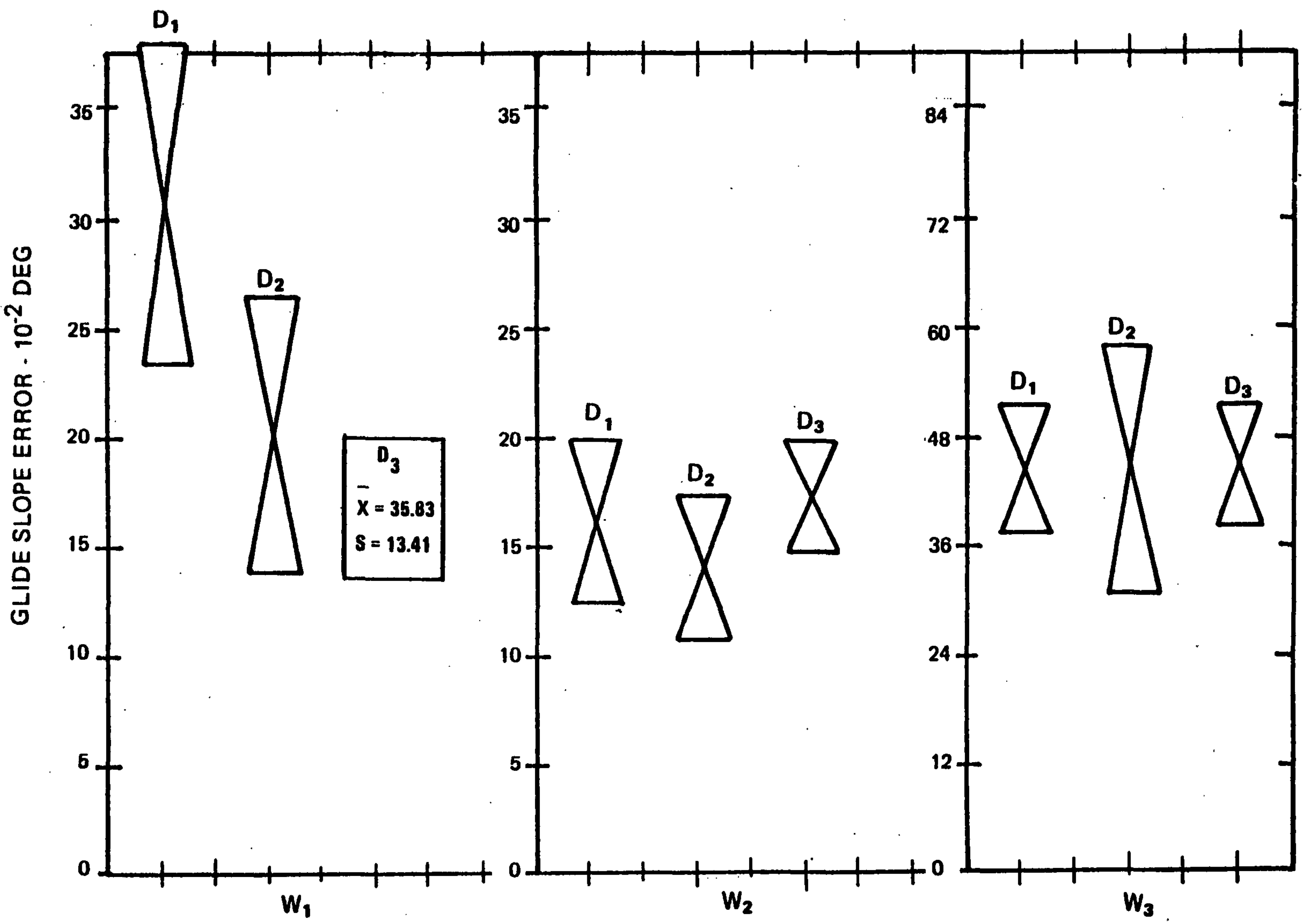

FIGURE 23 PILOT C GLIDE SLOPE MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

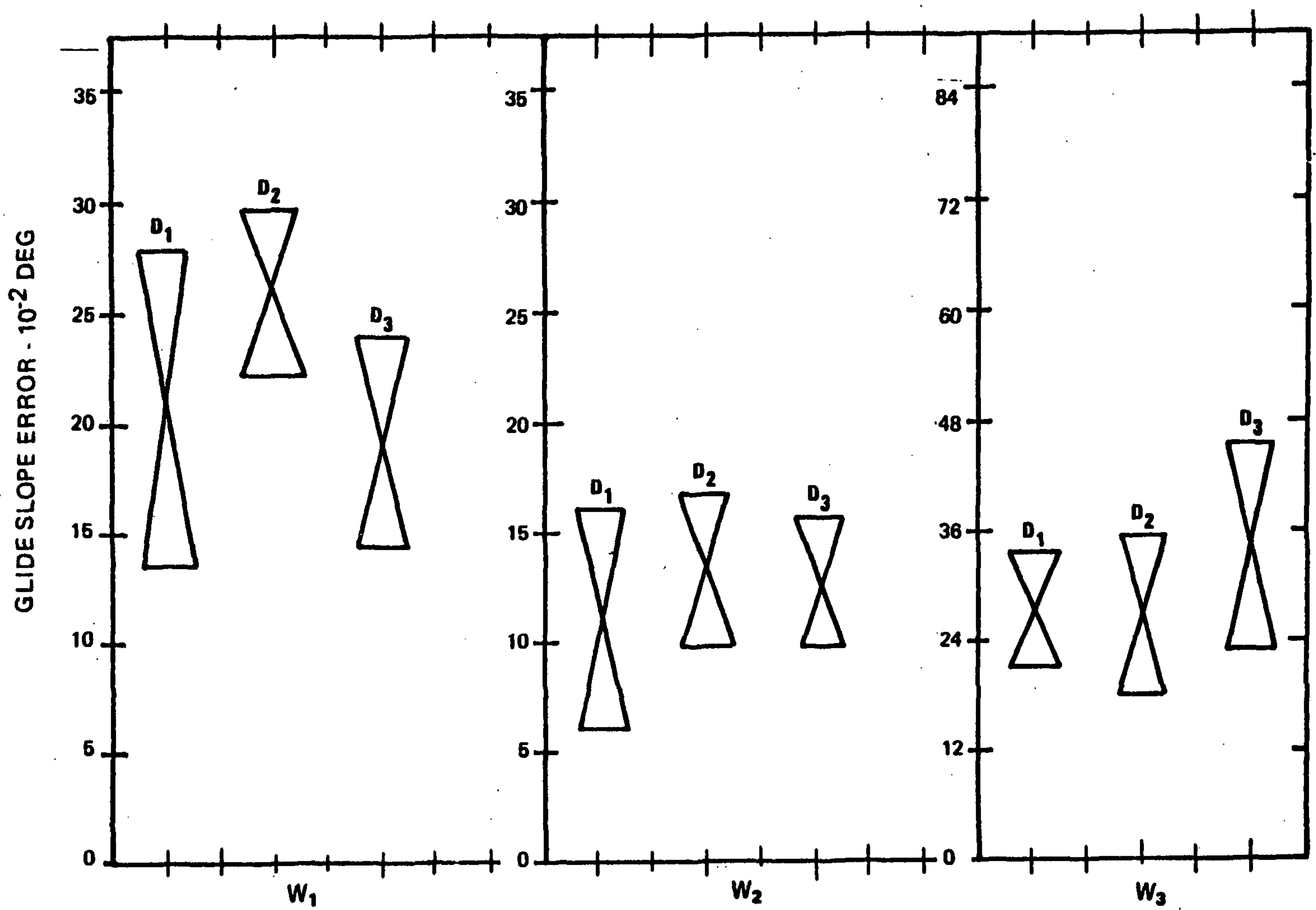

FIGURE 24 PILOT D GLIDE SLOPE MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

TABLE 1 - FAA WIND PROFILE B6

ALTITUDE		HEADWIND (KNOTS)	CROSSWIND (KNOTS)
m	ft.		
365.76	1200	26.4	-26.4
335.28	1100	26.4	-26.4
304.80	1000	25.4	-25.4
274.32	900	24.2	-24.2
243.84	800	22.8	-22.8
213.36	700	21.4	-21.4
182.88	600	19.7	-19.7
152.40	500	18.0	-18.0
121.92	400	22.3	-1.9
91.44	300	15.5	+10.8
60.96	200	3.6	+13.5
30.48	100	1.8	+6.8

NOTE: No turbulence is superimposed on the FAA Wind Profile B6.

TABLE 2 - FAA WIND PROFILE B7

RANGE		ALTITUDE		HEADWIND KNOTS	TAILWIND KNOTS	CROSSWIND KNOTS	VERTICAL WIND KNOTS
m	ft.	m	ft.				
15,240.0	50,000	609.6	2,000	10.88		-8.07	-9.10
4,196.2	13,767	214.0	702	5.83		-7.58	-1.22
3,779.8	12,401	194.1	637	2.62		-7.00	-0.41
3,363.2	11,034	174.6	573	0.00		-6.22	-1.07
2,946.5	9,667	155.1	509		7.39	-6.61	-2.04
2,530.1	8,301	127.1	417		10.50	-4.66	-2.92
2,113.2	6,933	108.5	356		19.24	-2.72	+0.02
1,696.5	5,566	81.7	268		20.51	-2.62	+0.37
1,279.5	4,198	60.3	198		21.48	-1.55	+0.17
863.8	2,834	45.4	149		24.68	+1.36	+0.23
447.1	1,467	19.2	63		16.52	+5.64	+0.00

NOTE: The following NASA/SRI turbulence is superimposed on the FAA Wind Profile B7.

AXIS	MEAN KNOTS	STANDARD DEVIATION KNOTS
Lateral	0	3.0
Longitudinal	0	4.0
Vertical	0	2.5

TABLE 3 - ANALYSIS OF VARIANCE OF LOCALIZER
TRACKING DATA FOR FAA WIND PROFILE B6

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.2751	.0917	16.23	4.00 (99%)**
DISPLAY TREATMENT	2	.0516	.0258	4.57	3.09 (95%)*
WINDOW TREATMENT	2	.4679	.2339	41.40	4.85 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0858	.0143	2.53	2.19 (95%)*
PILOT AND WINDOW TREATMENT	6	.1355	.0226	4.00	3.01 (99%)
WINDOW AND DISPLAY TREATMENT	4	.0173	.0043	0.76	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.0958	.0080	1.41	1.86 (95%)
ERROR	102	.5765	.00565		
TOTAL	137	1.7054			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 4 - ANALYSIS OF VARIANCE OF LOCALIZER
TRACKING DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.3069	.1023	7.63	3.99 (99%)**
DISPLAY TREATMENT	2	.0384	.0192	1.43	3.09 (95%)
WINDOW TREATMENT	2	.0008	.0004	0.03	3.09 (95%)
PILOT AND DISPLAY TREATMENT	6	.2706	.0451	3.36	2.99 (99%)**
PILOT AND WINDOW TREATMENT	6	.0199	.0033	0.25	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	.0296	.0074	0.55	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.0800	.0067	0.50	1.85 (95%)
ERROR	108	1.4478	.0134		
TOTAL	143	2.1939			

** An indication that the F (calculated) value is significant at the 99% level.

TABLE 5 - SUMMARY OF LOCALIZER MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.0432	.0441	.0338	.0419	.0237	.0295	.1256	.1595	.1408
	(S)	.0155	.0137	.0187	.0199	.0074	.0098	.0469	.0335	.0500
B	$(\bar{X})$	.0922	.0941	.0772	.1133	.2217	.1019	.2696	.4981	.2365
	(S)	.0568	.0464	.0329	.0326	.2205	.0669	.0757	.2618	.1387
C	$(\bar{X})$	.0681	.1053	.0983	.0703	.1122	.0807	.1937	.1486	.2910
	(S)	.0371	.0577	.0175	.0316	.0698	.0540	.0795	.0432	.0556
D	$(\bar{X})$	.0761	.0724	.0707	.0709	.0969	.0912	.1045	.1519	.1302
	(S)	.0361	.0286	.0236	.0136	.0136	.0442	.0335	.0398	.0438

NOTE: Localizer data values are given in degrees.

TABLE 6 -- SUMMARY OF LOCALIZER MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.0317	.0401	.0852	.0578	.0631	.0639	.0653	.0732	.0398
	(S)	.0080	.0083	.0357	.0127	.0329	.0169	.0159	.0499	.0098
B	$(\bar{X})$	.1612	.1782	.1012	.1355	.1322	.1280	.1909	.1571	.1365
	(S)	.0853	.0780	.0490	.1023	.0753	.0740	.1079	.0890	.1174
C	$(\bar{X})$	.0953	.0906	.4088	.0996	.1450	.3009	.1141	.1348	.2012
	(S)	.0494	.0552	.5161	.0245	.0843	.3011	.0394	.0820	.1039
D	$(\bar{X})$	.1288	.0772	.0601	.0720	.1279	.0920	.1093	.0881	.0808
	(S)	.0375	.0251	.0365	.0278	.0892	.0273	.0219	.0469	.0357

NOTE: Localizer data values are given in degrees.

TABLE 7 - ANALYSIS OF VARIANCE OF GLIDE SLOPE
TRACKING DATA FOR FAA WIND PROFILE B6

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.5224	.1741	14.04	4.00 (99%)**
DISPLAY TREATMENT	2	.2882	.0441	3.56	3.09 (95%)*
WINDOW TREATMENT	2	2.6902	1.3451	108.47	4.85 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0424	.0071	0.57	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	.4903	.0817	6.59	3.01 (99%)**
WINDOW AND DISPLAY TREATMENT	4	.0695	.0174	1.40	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.1528	.0127	1.02	1.86 (95%)
ERROR	102	1.2658	.0124		
TOTAL	137	5.3216			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 8 - ANALYSIS OF VARIANCE OF GLIDE SLOPE
TRACKING DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.2397	.0799	10.95	3.99 (99%)**
DISPLAY TREATMENT	2	.0965	.0483	6.60	4.83 (99%)**
WINDOW TREATMENT	2	1.9155	.9578	131.21	4.83 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0884	.0147	2.01	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	.2904	.0484	6.63	2.99 (99%)**
WINDOW AND DISPLAY TREATMENT	4	.0167	.0042	0.57	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.1040	.0087	1.19	1.85 (95%)
ERROR	108	.7883	.00730		
TOTAL	143	3.5396			

** An indication that the F (calculated) value is significant at the 99% level.

TABLE 9 - SUMMARY OF GLIDE SLOPE MEAN AND STANDARD DEVIATION
DATA FOR FAA WIND PROFILE B6

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.1826	.1614	.1862	.0913	.0828	.0739	.3777	.5345	.2631
	(S)	.0126	.0075	.0247	.0283	.0277	.0175	.2537	.1477	.0368
B	$(\bar{X})$	.2035	.2216	.1622	.1357	.2665	.1499	.6047	.6255	.5488
	(S)	.0810	.0611	.0334	.0517	.0788	.0730	.1902	.2772	.2246
C	$(\bar{X})$	.1627	.1745	.1726	.0951	.1305	.1148	.6324	.4909	.5402
	(S)	.0182	.0180	.0335	.0334	.0405	.0257	.1968	.1965	.2423
D	$(\bar{X})$	.1623	.1477	.1464	.0901	.1086	.1016	.2001	.3787	.1430
	(S)	.0100	.0153	.0259	.0192	.0326	.0262	.0442	.1244	.0591

NOTE: Glide slope data values are given in degrees.

TABLE 10 - SUMMARY OF GLIDE SLOPE MEAN AND STANDARD DEVIATION
DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.2496	.2445	.2717	.1284	.1188	.1624	.3778	.3884	.3958
	(S)	.0541	.0283	.0410	.0250	.0126	.0227	.0793	.0867	.1192
B	$(\bar{X})$	.1626	.1923	.2875	.1371	.1791	.2400	.5791	.4243	.7134
	(S)	.0525	.0729	.1164	.0250	.0498	.1830	.0940	.1535	.1931
C	$(\bar{X})$	.3082	.2036	.3583	.1619	.1432	.1760	.4508	.4519	.4598
	(S)	.0732	.0632	.1341	.0389	.0345	.0247	.0709	.1429	.0707
D	$(\bar{X})$	.2108	.2619	.1944	.1121	.1349	.1290	.2828	.2793	.3509
	(S)	.0738	.0392	.0449	.0496	.0358	.0308	.0656	.0886	.1149

NOTE: Glide slipe data values are given in degrees.

TABLE 11 -ANALYSIS OF VARIANCE OF ROLL FLIGHT DIRECTOR COMMAND DATA FOR FAA WIND PROFILE B6

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.0877	.02923	19.75	4.00 (99%)**
DISPLAY TREATMENT	2	.0085	.00425	2.87	3.09 (95%)
WINDOW TREATMENT	2	.0332	.0166	11.22	4.85 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0162	.0027	1.82	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	.0048	.00080	0.54	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	.0005	.000130	0.09	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.0115	.00096	0.64	1.86 (95%)
ERROR	102	.15125	.00148		
TOTAL	137	.31358			

** An indication that the F (calculated) value is significant at the 99% level.

TABLE 12 - ANALYSIS OF VARIANCE OF ROLL FLIGHT DIRECTOR COMMAND DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.0737	.02457	11.75	3.99 (99%)**
DISPLAY TREATMENT	2	.0012	.0006	0.29	3.09 (95%)
WINDOW TREATMENT	2	.0031	.00155	0.74	3.09 (95%)
PILOT AND DISPLAY TREATMENT	6	.0348	.0058	2.78	2.19 (95%)*
PILOT AND WINDOW TREATMENT	6	.0173	.00288	1.38	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	.0038	.00095	0.45	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.0243	.00203	0.97	1.85 (95%)
ERROR	108	.22556	.00209		
TOTAL	143	.38383			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 13- SUMMARY OF ROLL FLIGHT DIRECTOR COMMAND MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.0374	.0337	.0296	.0380	.0272	.0243	.0525	.0559	.0584
	(S)	.0103	.0143	.0083	.0141	.0060	.0046	.0259	.0207	.0179
B	$(\bar{X})$	.0803	.1061	.0811	.0775	.1371	.0731	.1318	.1898	.1123
	(S)	.0350	.0702	.0259	.0387	.1300	.0297	.0674	.0590	.0451
C	$(\bar{X})$	.0667	.0724	.0689	.0567	.0682	.0714	.0882	.0738	.1292
	(S)	.0308	.0375	.0193	.0147	.0424	.0236	.0122	.0220	.0288
D	$(\bar{X})$	.0709	.0829	.0644	.0696	.0795	.1045	.1087	.1159	.0912
	(S)	.0326	.0254	.0153	.0194	.0114	.0148	.0264	.0555	.0406

NOTE: Roll flight director command data values are given in degrees.

TABLE 14 - SUMMARY OF ROLL FLIGHT DIRECTOR COMMAND MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.0413	.0470	.0686	.0497	.0544	.0476	.0638	.0535	.0510
	(S)	.0158	.0155	.0208	.0051	.0100	.0125	.0139	.0132	.0125
B	$(\bar{X})$	.0791	.1169	.0632	.1154	.0971	.1003	.1387	.1125	.1555
	(S)	.0085	.0403	.0157	.0508	.0175	.0477	.0447	.0663	.0898
C	$(\bar{X})$	.0643	.1093	.1925	.0846	.0955	.1294	.0820	.0994	.1080
	(S)	.0194	.0532	.1792	.0210	.0152	.0686	.0270	.0400	.0351
D	$(\bar{X})$	.1047	.0750	.0500	.0827	.0966	.0705	.1152	.0874	.0682
	(S)	.0255	.0163	.0244	.0131	.0442	.0272	.0316	.0454	.0140

NOTE: Roll flight director command data values are given in degrees.

TABLE 15 - ANALYSIS OF VARIANCE OF PITCH FLIGHT DIRECTOR COMMAND DATA FOR FAA WIND PROFILE B6

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.1151	.038367	43.64	4.00 (99%)**
DISPLAY TREATMENT	2	.0075	.00375	4.27	3.09 (95%)*
WINDOW TREATMENT	2	.0211	.01055	12.00	4.85 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0098	.001633	1.85	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	.0132	.0022	2.50	2.19 (95%)*
WINDOW AND DISPLAY TREATMENT	4	.0023	.000575	0.65	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.0075	.000625	0.71	1.86 (95%)
ERROR	102	.08963	.000879		
TOTAL	137	.26606			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 16 - ANALYSIS OF VARIANCE OF PITCH FLIGHT DIRECTOR COMMAND DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.0892	.02973	20.09	3.99 (99%)**
DISPLAY TREATMENT	2	.0142	.0071	4.80	3.09 (95%)*
WINDOW TREATMENT	2	.0325	.01625	10.98	4.83 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0224	.00373	2.52	2.19 (95%)*
PILOT AND WINDOW TREATMENT	6	.0111	.00185	1.25	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	.0015	.00038	0.26	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.0259	.00216	1.46	1.85 (95%)
ERROR	108	.15985	.00148		
TOTAL	143	.35663			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 17 - SUMMARY OF PITCH FLIGHT DIRECTOR COMMAND MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.0403	.0434	.0462	.0341	.0377	.0328	.0806	.0895	.0650
	(S)	.0101	.0249	.0202	.0177	.0071	.0153	.0204	.0106	.0055
B	$(\bar{X})$	.1562	.1658	.1213	.0702	.1469	.1019	.1162	.1535	.1283
	(S)	.0797	.0565	.0352	.0243	.0385	.0490	.0069	.0323	.0346
C	$(\bar{X})$	.0569	.0615	.0930	.0582	.0707	.0785	.1162	.0916	.1244
	(S)	.0174	.0187	.0379	.0141	.0314	.0206	.0425	.0133	.0513
D	$(\bar{X})$	.0762	.0647	.0794	.0477	.0664	.0581	.0593	.0819	.0695
	(S)	.0312	.0082	.0292	.0127	.0133	.0145	.0194	.0137	.0364

NOTE: Pitch flight director command data values are given in cm.

TABLE 18 - SUMMARY OF PITCH FLIGHT DIRECTOR COMMAND MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.1224	.0813	.1160	.0846	.0748	.0967	.1068	.1087	.1102
	(S)	.0561	.0139	.0297	.0090	.0084	.0081	.0235	.0228	.0257
B	$(\bar{X})$	.1427	.1597	.2060	.1217	.1165	.1595	.1558	.1240	.2315
	(S)	.0191	.0684	.1110	.0209	.0207	.0607	.0328	.0213	.0632
C	$(\bar{X})$	.1937	.1321	.2093	.1332	.1144	.0910	.1315	.1511	.1406
	(S)	.0542	.0199	.0573	.0226	.0037	.0253	.0428	.0633	.0163
D	$(\bar{X})$	.1119	.1332	.0980	.0860	.0900	.1063	.1114	.0935	.1044
	(S)	.0346	.0181	.0276	.0159	.0197	.0290	.0172	.0393	.0130

NOTE: Pitch flight director command data values are given in cm.

TABLE 19 - ANALYSIS OF VARIANCE OF PILOT WHEEL INPUT DATA FOR FAA WIND PROFILE B6

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	147.56	49.18	21.38	4.00 (99%)**
DISPLAY TREATMENT	2	9.70	4.85	2.11	3.09 (95%)
WINDOW TREATMENT	2	348.54	174.27	75.77	4.85 (99%)**
PILOT AND DISPLAY TREATMENT	6	3.43	0.57	0.25	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	10.97	1.83	0.08	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	4.26	1.06	0.46	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	37.11	3.09	1.34	1.86 (95%)
ERROR	102	235.01	2.30		
TOTAL	137	796.60			

** An indication that the F (calculated) value is significant at the 99% level.

TABLE 20 - ANALYSIS OF VARIANCE OF PILOT WHEEL INPUT DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	43.21	14.40	2.87	2.70 (95%)*
DISPLAY TREATMENT	2	17.10	8.55	1.70	3.09 (95%)
WINDOW TREATMENT	2	146.79	73.39	14.61	4.83 (99%)**
PILOT AND DISPLAY TREATMENT	6	62.71	10.45	2.08	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	21.51	3.58	0.71	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	16.68	4.17	0.83	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	28.39	2.36	0.47	1.85 (95%)
ERROR	108	542.75	5.02		
TOTAL	143	879.18			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 21- SUMMARY OF PILOT WHEEL INPUT MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	3.79	3.71	4.16	4.24	3.57	3.82	6.52	8.03	7.35
	(S)	0.78	0.69	1.00	0.44	0.34	0.45	2.19	3.47	0.53
B	$(\bar{X})$	5.69	5.45	7.67	6.68	8.04	6.98	10.58	10.92	9.63
	(S)	0.84	1.17	1.15	1.86	1.73	1.64	2.28	1.77	1.80
C	$(\bar{X})$	4.23	4.92	5.20	5.18	5.75	5.65	8.67	7.13	9.59
	(S)	1.47	2.41	1.25	1.57	2.34	0.52	0.96	0.78	1.29
D	$(\bar{X})$	4.93	4.63	4.04	5.75	6.53	6.77	7.43	9.74	8.05
	(S)	1.86	1.91	0.51	1.10	0.36	0.45	1.25	3.11	0.68

NOTE: Pilot wheel input data is given in degrees.

TABLE 22 - SUMMARY OF PILOT WHEEL INPUT MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	5.45	6.42	7.48	6.86	7.62	7.27	7.39	8.12	7.01
	(S)	2.14	1.17	1.59	1.20	0.80	1.39	2.07	3.35	2.58
B	$(\bar{X})$	6.61	8.46	6.82	6.60	7.58	9.46	10.96	9.58	9.50
	(S)	1.09	2.45	1.24	1.54	1.25	1.48	1.93	4.47	2.16
C	$(\bar{X})$	4.17	6.39	8.57	6.08	7.61	9.23	8.47	8.84	10.14
	(S)	1.35	1.28	5.87	1.49	1.00	4.71	1.91	2.03	3.07
D	$(\bar{X})$	6.21	6.16	4.26	6.96	7.34	6.25	9.19	9.43	7.89
	(S)	1.45	0.79	1.75	1.67	1.78	0.66	1.10	2.76	0.92

NOTE: Pilot wheel input data is given in degrees.

TABLE 23 - ANALYSIS OF VARIANCE OF PILOT COLUMN INPUT DATA
FOR FAA WIND PROFILE B6

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.4266	.1422	7.94	4.00 (99%)**
DISPLAY TREATMENT	2	.0961	.0480	2.68	3.09 (95%)
WINDOW TREATMENT	2	5.9678	2.9839	166.69	4.85 (99%)**
PILOT AND DISPLAY TREATMENT	6	.0615	.0102	0.57	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	.3055	.0509	2.84	2.19 (95%)*
WINDOW AND DISPLAY TREATMENT	4	.0547	.0136	0.76	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.2267	.0188	1.05	1.86 (95%)
ERROR	102	1.8240	.0179		
TOTAL	137	8.9639			

* An indication that the F (calculated) value is significant at the 95% level.
** An indication that the F (calculated) value is significant at the 99% level.

TABLE 24 - ANALYSIS OF VARIANCE OF PILOT COLUMN INPUT DATA
FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

SOURCES	df	SS	MS	F_C	F_T
PILOT TREATMENT	3	.5737	.1912	5.81	3.99 (99%)**
DISPLAY TREATMENT	2	.0259	.0129	0.39	3.09 (95%)
WINDOW TREATMENT	2	4.2822	2.1411	65.07	4.83 (99%)**
PILOT AND DISPLAY TREATMENT	6	.2729	.0455	1.38	2.19 (95%)
PILOT AND WINDOW TREATMENT	6	.4189	.0698	2.12	2.19 (95%)
WINDOW AND DISPLAY TREATMENT	4	.0470	.0117	0.36	2.47 (95%)
PILOT AND WINDOW AND DISPLAY TREATMENT	12	.3017	.0251	0.76	1.85 (95%)
ERROR	108	3.5590	.0329		
TOTAL	143	9.4817			

** An indication that the F (calculated value is significant at the 99% level.

TABLE 25 - SUMMARY OF PILOT COLUMN INPUT MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B6

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.3047	.3273	.2979	.2120	.2517	.2328	.7359	.9216	.8835
	(S)	.0793	.0846	.1100	.0868	.0871	.1007	.1987	.2408	.1720
B	$(\bar{X})$	.4414	.4987	.4110	.3385	.6680	.4420	.7874	.7715	.8069
	(S)	.0660	.1106	.0381	.0691	.2836	.1236	.2008	.2219	.1333
C	$(\bar{X})$	.2538	.3028	.3599	.2399	.2517	.2256	.7294	.7123	.7805
	(S)	.0300	.0443	.0403	.0713	.0759	.0434	.0802	.0313	.2114
D	$(\bar{X})$	.3193	.3307	.4194	.3270	.3732	.2969	.8078	.8041	.6423
	(S)	.0514	.0130	.1745	.0920	.1035	.0598	.1097	.2061	.2551

NOTE: Pilot column input data is given in inches.

TABLE 26 - SUMMARY OF PILOT COLUMN INPUT MEAN AND STANDARD DEVIATION DATA FOR FAA WIND PROFILE B7 PLUS NASA/SRI TURBULENCE

PILOT		W_1			W_2			W_3		
		D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
A	$(\bar{X})$	.8695	.7114	.8463	.7294	.6435	.6497	1.1854	1.2226	1.2248
	(S)	.1230	.0471	.1243	.0835	.1553	.1770	.1615	.2421	.2511
B	$(\bar{X})$	.5790	.7734	.7771	.7145	.7061	.7920	1.0016	.9758	1.3063
	(S)	.1543	.3828	.0629	.1655	.1615	.1255	.1019	.3205	.2867
C	$(\bar{X})$	.7235	.5781	.6172	.6609	.6401	.6324	.8630	.9554	.9002
	(S)	.2117	.1763	.0930	.1385	.1184	.1150	.1987	.2256	.1667
D	$(\bar{X})$	.6479	.7768	.5762	.8490	.7700	.8425	1.1466	1.0952	1.0639
	(S)	.1794	.1466	.1432	.0582	.1565	.1844	.1150	.2802	.1658

NOTE: Pilot column input data is given in inches.

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Final Report

16. Abstract

This report presents the results of a piloted-simulation experiment to evaluate the effect of integrating flight path angle information into a typical transport electronic attitude director indicator (EADI) display format for flight director ILS approaches. Three electronic display formats were evaluated during 3° straight-in approaches with wind shear and turbulence conditions. Flight path tracking data and pilot subjective comments were analyzed with regard to the pilot's tracking performance and workload for all three display formats.

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